SUMMARY RESOURCE DESCRIPTION

UPPER MISSISSIPPI RIVER SYSTEM

Volume 4

Biology

Prepared by:

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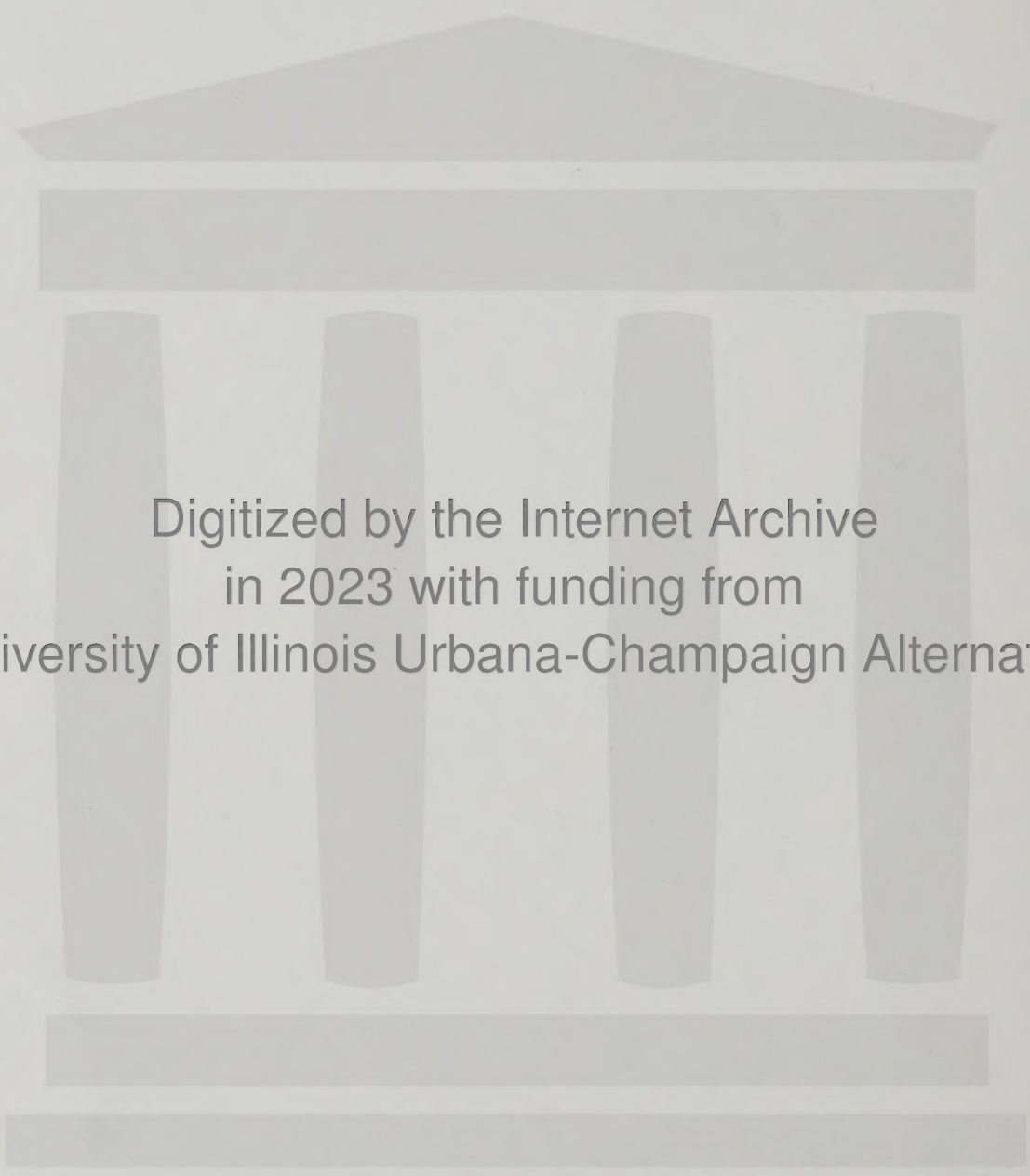
July 1981



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PREFACE

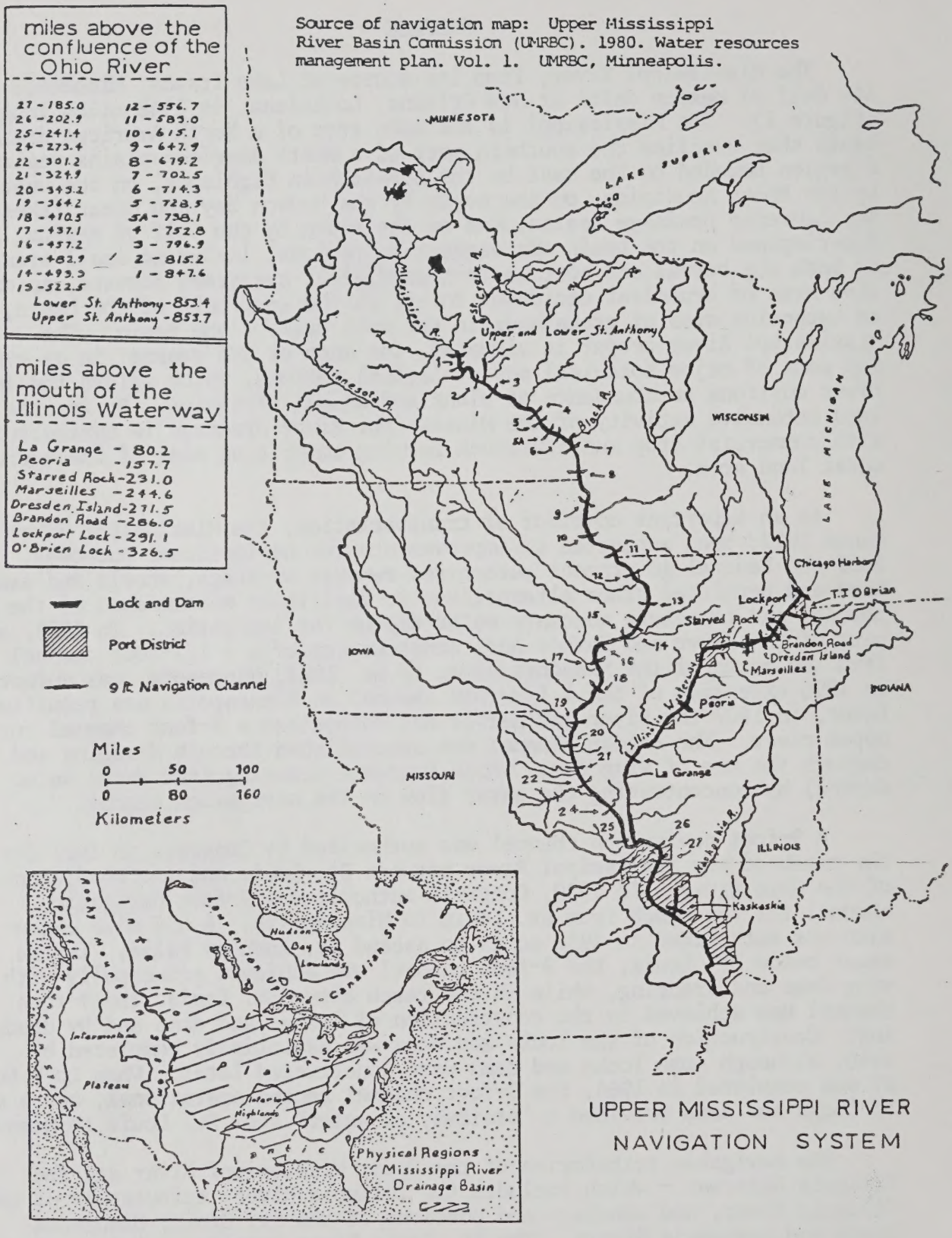
The Mississippi River, from its source at Lake Itasca, Minnesota to its Gulf of Mexico delta at New Orleans, Louisiana, is 2348 miles long (Figure 1). The Mississippi is the main stem of a North American drainage basin that overlies the southern part of a North American plains region, a region bounded on the east by the Appalachian Highlands, on the west by the Rocky Mountains, on the north by the Hudson Bay and Great Lakes-St. Lawrence Drainage Basins, and on the south by the Gulf of Mexico. Superimposed on the basin are vegetation regions, including small areas of both the boreal and southeastern needleleaf evergreen forests, an extensive area of broadleaf deciduous forest in the east half of the basin, and an extensive area of grasslands in the west half of the basin. The Mississippi River proper is situated, for much of its course, in an overlap zone of major botanical and zoological regions, which afford the local river environs an abundance of plant and animal varieties. By far the most land extensive activity of the Mississippi River Drainage is agriculture, with commercial crop and livestock farming comprising most of the agricultural land area.

As an important corridor of transportation, the Mississippi River has, since 1822, been subjected to improvements for navigational purposes. In 1822 the Federal government authorized removal of snags, shoals and sandbars and permitted other alternatives to facilitate maintenance of the main channel and to assure adequate water depths for navigation. In 1878, as part of the River and Harbor Act, construction of a 4 1/2-foot channel from the mouth of the Missouri River to St. Paul, Minnesota, was authorized; in 1890 extension of the 4 1/2-foot channel to Minneapolis was permitted. Later, in 1907 the River and Harbor Act authorized a 6-foot channel for the upper river. The 6-foot channel was accomplished through dredging and through the use of wing dams, which increase scouring (and raise water depths) by concentrating the water flow in the navigation channel.

A 9-foot navigation channel was authorized by Congress in 1927 for the reach of the Mississippi River between St. Louis and the confluence of the Ohio River. In 1930, Congress authorized a 9-foot navigation channel for the reach from St. Louis to Minneapolis. A 4.6 mile extension was authorized in 1937 so as to ascend St. Anthony Falls. In the reach below St. Louis, the 9-foot channel was achieved principally with wing dams and dredging, while in the reach above St. Louis, the 9-foot channel was achieved by the construction of locks and dams and by dredging. Construction of the locks and dams was essentially completed by 1940, although some locks and dams were constructed later. When Lock No. 27 was completed in 1964, the 9-foot channel became operational, and a series of locks and dams provided a "stairway of water" from St. Louis to Minneapolis.

The navigable tributaries of the Upper Mississippi River are the Illinois Waterway - which includes the Illinois River, tributaries of the Illinois River, and canals - and portions of the St. Croix, Minnesota, Black and Kaskaskia Rivers. The St. Croix River provides a 9-foot channel for 24.5 miles from its mouth at Prescott, Wisconsin. The Minnesota River has a 9-foot channel from its mouth in St. Paul to mile 21.8. The Black River is navigable by commercial vessels for only 1.4 miles from its mouth

FIGURE 1



Source of navigation map: Upper Mississippi River Basin Commission (UMRBC). 1980. Water resources management plan. Vol. 1. UMRBC, Minneapolis.

UPPER MISSISSIPPI RIVER NAVIGATION SYSTEM

Source of physical region map: Oxford regional economic atlas: United States and Canada. 1967. Clarendon Press, Oxford.

at La Crosse, Wisconsin. The Kaskaskia River presently has a 9-foot channel for 24.8 miles from its mouth, located 60 miles below St. Louis; an eleven-mile channel extension to Fayetteville, Illinois is to be opened to commerce in the near future. The Kaskaskia has one lock and dam, which is less than a mile upstream from its mouth. The Illinois Waterway, a connection between the St. Lawrence-Great Lakes and Mississippi-Ohio-Missouri navigation systems, extends from its mouth, located 35 miles above St. Louis, Missouri, to Chicago, Illinois, a distance of 327 miles. The Illinois Waterway 9-foot channel, completed in the 1930s, has a series of eight locks and dams.

ACKNOWLEDGEMENTS

Work performed for the overall project, of which this report is a part, formed the basis for this report. Gordon G. Plorin, a doctoral student in the Department of Ecology and Behavioral Biology, University of Minnesota - Twin Cities, worked in the early stages of the project and was instrumental in establishing both its direction and scope.

Critical reviews of a draft of the report were received from Dr. Calvin R. Fremling, Department of Biology, Winona State University, Winona, Minnesota; Dr. James C. Underhill, Department of Ecology and Behavioral Biology, University of Minnesota - Twin Cities; and Dr. Thomas F. Waters, Department of Entomology, Fisheries, and Wildlife, University of Minnesota - Twin Cities. Written critiques of a draft of the report were also received from individuals in the following organizations: Illinois Department of Conservation; Missouri Department of Natural Resources; U.S. Army Engineer Districts of St. Louis and St. Paul; U.S. Army Engineer Waterways Experiment Station, Vicksburg, Mississippi; and U.S. Fish and Wildlife Service, Rock Island office.

Personal consultation during the project was received from Drs. Calvin R. Fremling and James C. Underhill. Dr. Gerald B. Ownbey, Department of Botany, University of Minnesota - Twin Cities, was consulted regularly on questions of plant taxonomy. The staff of the Minnesota State Planning Agency, Land Management Information Center (LMIC), helped design, store, and access the computerized bibliographic file that was created as part of this project. Janeen E. McAllister of LMIC worked closely with the project from its inception.

Appreciation is extended to the staffs of the organizations that cooperated with the information requests of the project: Midwest Research Institute, Minnetonka, Minnesota; Minnesota Department of Natural Resources, Lake City and St. Paul office; Upper Mississippi River Basin Commission; Upper Mississippi River Conservation Committee; U.S. Army Engineer Districts of Chicago, Rock Island, St. Louis and St. Paul; and U.S. Fish and Wildlife Service, Iowa State Cooperative Fisheries Unit, La Crosse and Rock Island office, Mark Twain Wildlife Refuge, and Upper Mississippi River Wildlife and Fish Refuge.

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INTRODUCTION

This paper is a summary description of the current biological characteristics of the Upper Mississippi River System, and an assessment of the quality and completeness of information for such a biological description. Information collection and evaluation for the paper were directed toward those organisms that are closely associated with the navigation system. Consequently, aquatic organisms were allotted most of the available time, while semi- and non-aquatic organisms were allotted significantly less time. The rather cursory treatment of semi- and non-aquatic organisms, compared with the fuller treatment of aquatic organisms, is not, therefore, an accurate reflection of the respective amounts of information available on the types of organisms. In addition, the paper was designed to describe baseline data, and it did not deal with, for example, economic, recreational, or management questions or projects, even if such questions or projects were entirely concerned with biological matters.

As a "summary description", information is treated at a high level of generality. Descriptions are made from a particular perspective, which is to compare, over space and usually over time, the abundance and diversity of aquatic organisms and their habitats.

The "description" of biological characteristics is a less powerful phrase than the "explanation" of biological characteristics. A description of the character of an object is a necessary part of explaining that object, but explanation goes further. Explanation is a satisfactory answer to the question of why that object has those characteristics, or why a particular spatial or temporal pattern to the characteristics of that object was experienced. The difference between explanation and description is made explicit, because the thorough literature reviews that are necessary to make explanatory statements were not the emphasis of this project. Explanations and reasoned conjectures that were found in the literature are included in the discussion.

The initial part of the presentation in the paper is a broad characterization of the present distribution of aquatic and terrestrial habitats of the streams in the study area. It includes a discussion of the principal historical processes that have created the current distribution of habitats and the major processes that are now affecting the habitats. The discussion is directed next to benthic macroinvertebrates (bivalves, gastropods, oligochaetes, insects, others), and then zooplankton, phytoplankton, fishes, vertebrates other than fishes and, finally, aquatic and terrestrial vegetation. The discussions of these organisms are summary descriptions of their abundance and diversity, and the adequacy of information for a summary description.

The overall project, of which this paper is a portion, was to assemble information sources on the current diversity and abundance of those species that are closely associated with the streams of the nine-foot navigation channel of the Upper Mississippi River System. The sources of this information are stored in an annotated bibliographic computer file. This file is referred to in the text of the paper as "Supplement A". The file contains literature citations and listings of sampled organisms by sample date, location, and type of sample (population or type data on a species).

Supplement A contains an author index and a subject index. The subject index is organized by literature source, sampling data, and general category of sampled organism (fish, wildlife, benthos, phytoplankton, zooplankton, and other flora). A "Guide" to the bibliographic file has been prepared. The "Guide" describes the structure of the file and how the file can be utilized in automated searches for literature on specific topical areas, organisms, and geographic regions.

CONCLUSIONS

Reaches of the Upper Mississippi River have similar characteristics in terms of general aquatic habitats. The pooled river above Dam 13, compared to the pooled river below Dam 13, is characterized by a large amount of water surface area that is off the main channel and by a sizable cover of aquatic vegetation. In the pooled section below Dam 13, a greater proportion of total water surface area is found in the main channel and the coverage of aquatic vegetation diminishes. The open (unimpounded) river between St. Louis and the confluence of the Ohio River is characterized by a paucity of both off-channel waters and aquatic vegetation. Outstanding exceptions to, or extremes of, the above broad generalizations are a part of the unique geological history of a reach (gorge of Pool 1, and Lake Pepin in Pool 4), or are of an origin not explained in this study (small coverages of aquatic vegetation in Pools 15, 20, 21,and 22). The minor expanse of aquatic vegetation in the open river is partially due to a high turbidity and sediment load. The Missouri River has traditionally been a major contributor to the turbidity and sediment load of this open (unimpounded) reach of the Upper Mississippi River.

The history of human activity on and off the Mississippi River is a major determinant of the current distribution of aquatic habitats, and of the processes that are altering the habitats. Of such human activities, the stream improvement techniques that have been utilized for the maintenance of commercial navigation are of primary importance. The water surface area of the open river has been constricted as a result of channel maintenance activities, whereas water surface area was expanded above St. Louis by the impoundment of the river for the nine-foot navigation channel. Much of the current difference between the impounded and open reach in terms of the size and diversity of aquatic habitats is a direct result of the different stream improvement techniques that were used on the two reaches to achieve adequate channel depths for navigation.

Impoundment of the river expanded the slack-water area and stabilized water levels, creating favorable conditions, at least initially, for aquatic vegetation. In contrast, slack-water area has been lost and water levels have not been moderated by the channel improvement techniques utilized on the open river. The open river, subsequently, is a less favorable setting, in general, for aquatic vegetation than the pooled river.

Impoundment diminished the ability of the river to transport sediment, because it expanded the width and depth of the river and, thereby, lessened river velocity. Sedimentation is of concern throughout the pooled reach of the river. The rapid rate at which fine sediment has accumulated in river lakes and sloughs, and at which it continues to be generated in the drainage basin do not lead to an optimistic outlook for the diversity of aquatic habitats in the pooled reach of the Mississippi River. Siltation has, since impoundment, reduced the surface area and volume of the backwaters. Lakes and sloughs, which had diverse bottom depths, have been transformed into expanses of shallower water of more uniform depth. The loss in diversity in bottom depths has simplified the range of habitats for aquatic vegetation. Some of the newly created shallows have been colonized by aquatic vegetation, but continued siltation will promote

succession to terrestrial vegetation. Siltation, in addition, has an effect on turbidity levels, which, in turn, affect the growth (photosynthetic activity) of aquatic plants. The synergistic effects of turbidity and siltation on aquatic habitat diversity have been felt more severely throughout the Illinois River than throughout the Mississippi River. Evidence suggests that the lowest pools of the Mississippi River have recently begun to be seriously affected by silt and turbidity.

The ability to describe the composition of the aquatic and terrestrial flora of the Mississippi River was greatly enhanced by 1975 remote-sensing assessments of the river from Pool 3 to the Ohio River. In these assessments, flora is typed by general categories, which are identified by the dominant plant genus or species in the category, or by the dominant association of genera or species in the category, or by the human use of the plant, for example, agricultural crops. The assessment of submergent aquatic macrophytes, however, was neither completely full, due to covering plants, nor completely reliable, due to the ability to "see" the submergent aquatic beds through the turbidity of the Mississippi River. Large expanses of submergent aquatic beds were found, however, in Pools 7 to 9, with lesser expanses in Pools 3 to 6, 10 to 13, and 19. Elsewhere, submergent aquatic coverage was minor or zero. The principal submergent aquatic species identified with the typing categories in the reach from Pool 3 to 10 were coontail, pondweeds and wild celery. Below Pool 10, submergent aquatic plants were all typed "submergent". The primary emergent and floating aquatic plant species identified with the typing categories from Pool 3 to the Ohio River are ubiquitous species: duck potato, bulrushes, smartweeds, water lilies and duckweeds.

The remote sensing of vegetation sacrifices detail for areal coverage. Detail can be gained through intensive works in particular river reaches. For the Mississippi, Minnesota, St. Croix and Kaskaskia River, such detailed works on aquatic vegetation were not found, except in a few reaches. Noteworthy are the studies of Pools 7 and 8, and, to a lesser degree, the studies in Pools 3 to 6, 9, 10, 19, and 24 to 26. In other Mississippi reaches, and in the Minnesota, St. Croix and Kaskaskia River, aquatic vegetation sampling was found to be nonexistant or virtually nonexistant. Furthermore, most studies dealt with plant typing only and not with the relative distribution and biomass of the plant species.

Compared with the Mississippi River, major historical land/water alterations along the valley of the Illinois Waterway were not as solely due to the alteration wrought by the impoundment of the river for navigation. Impoundment was a principal factor that accounts for the current distribution of aquatic habitats on the Illinois Waterway, but additional major factors are the Lake Michigan diversion, agricultural levee and drainage districts, and (to a greater overall extent than on the Mississippi River) sedimentation. The Illinois Waterway contains three long pools (Alton, La Grange and Peoria) that cover two-thirds of the length of the Waterway and are located in the section of the Illinois River with a relatively gentle bottom gradient. These long pools contain most of the aquatic habitat of the Waterway, and can be characterized, before and after completion of the nine-foot channel, by large expanses of bottomland

lakes. The shorter pools above Peoria are located in the section of the Illinois Waterway with a steeper bottom gradient and do not contain the expanses of bottomland lakes that characterize the lower Waterway.

Impoundment of the Illinois River for the nine-foot channel in the 1930s, in conjunction with a sizable drop in Lake Michigan diversion in the 1930s, decreased river velocity and increased sedimentation. Sediment has rapidly filled the backwaters, and former open water areas and aquatic vegetation beds have been converted to terrestrial vegetation and seasonally exposed mud flats. In addition to a physical loss of aquatic habitat caused by sedimentation, sediment and its attendant turbidity have virtually eradicated the submergent and floating aquatic plants along the Illinois River, and have been prime contributors to the simplification and loss of emergent aquatic plant beds. The high turbidity inhibits photosynthesis, and the rapid rate of siltation has created a soft, "false" bottom that provides poor root anchorage against the buffeting action of the wind. What persists of the aquatic vegetation are residual beds of species that are highly tolerant to turbidity and fluctuating water levels. Due to the loss of aquatic plants, moist-soil plants have risen in importance as a resource, especially as a food source for waterfowl. Moist-soil plants volunteer on the seasonal mud flats that were expanded in size by the filling of bottomland lakes and sloughs with sediment.

Impoundment of the Mississippi River apparently had a substantially lesser effect on the commercially navigable segments of the Minnesota and St. Croix River than on the Mississippi River proper. In contrast, the diversity of aquatic habitats of the Kaskaskia River was materially altered by the preparation of the lower river for commercial navigation. One segment of the navigable reach of the Kaskaskia River was channelized, while the other segment was canalized for the nine-foot channel.

Mussel populations of the Upper Mississippi River have been surveyed in several major studies during the 20th century, and data thus permit assessments of change. The Mississippi River and some of its tributaries have been, and remain, among the world's prime mussel habitats. Forty-six species of mussels were recorded in pre-1964 surveys, and 43 species have been collected post-1964. There is a paucity of mussels in the uppermost pools, but mussel populations increase downstream from the Twin Cities. Mussels occur in considerable variety in Lake Pepin (Pool 4), and the number of species increases below Pool 4.

A slight decline in mussel species in the Upper Mississippi River may mask a more significant change -- a change in species composition. The dominant species now is Amblema plicata, a species that is very tolerant of adverse habitat conditions. Agricultural, industrial, and domestic inputs to the river are likely to have taken a considerable toll on mussel fauna. Two endangered mussels, Proptera capax and Lampsilis higginsi, are known from the Mississippi River. The former has recently been collected only subfossilized in Pool 24, while the latter has been collected from various sites. Lampsilis higginsi seems to be well suited to a recovery program. Cumberlandia monodonta, a species that occurs in rocky areas, warrants special attention because of the demise of habitats as a result of channel maintenance. This species has recently been collected from five pools.

Fingernail clams, recognized as indicators of organic pollution, are important sources of food for fish and waterfowl. Recent unexplained population crashes of fingernail clams in the Illinois River coincided with a decline in the number of diving ducks using the Illinois River as a stopover. Subsequently, some of these ducks may then have begun to use Pool 19 of the Mississippi River as an alternative stopover.

One of the most striking malacological events in the Upper Mississippi River involves the establishment of the Asiatic clam (Corbicula manilensis). First reported in the United States in 1938, this clam is now common in the lower reaches of the Upper Mississippi River. Corbicula has been reported as far upstream as Pool 9, and even further north in the lower St. Croix River. It has also been collected from the Illinois and Kaskaskia Rivers.

Unlike the bivalves, the gastropods of the Upper Mississippi are not particularly well studied. The species that have been collected are ubiquitous or, at least, common inhabitants of large rivers.

Other than mussels, the oligochaetes and insects comprise major components of benthic biomass. Tubificid oligochaetes are indicators of organic pollution, but the concept of indicator organisms has not been applied to the Upper Mississippi River. In general, oligochaetes in the Mississippi have been poorly studied. Insects, in contrast, have been well studied. Ephemeroptera (especially Hexagenia) and Trichoptera (especially Cheumatopsyche and Hydropsyche) are among the most abundant benthic organisms in the Mississippi River. Both the mayflies and caddisflies seem to be increasing as a result of construction of the navigation systems. Both groups provide a tremendously important source of fish food, and both groups reach nuisance levels at times.

Zooplankters include many species that are very important in the food chain as intermediates between algae, bacteria, and protozoans on the one hand, and plankton predators (mainly fish) on the other. Generally speaking, zooplankton in the Mississippi River is poorly studied. They seem to be almost nonexistent in waters carrying large amounts of sand and silt, but populations may be very high in silt-free habitats. Zooplankton populations are believed to influence phytoplankton densities by exerting grazing pressure during the bloom. Zooplankton densities are generally low throughout the Illinois River, but they increase in the lower reaches.

Phtyoplankters are important in surface waters, where they fix solar energy which can then be used in other trophic levels in the aquatic food chain. Phytoplankton is significantly more abundant during average river states of the warm season than at higher stages.

Compared with other organisms, fish have been the subject of extensive monitorings, utilizing sampling stations, test and exploratory fishing, creel surveys, aerial surveys, and tagging and marking programs. A total of 139 species of fish has been identified in the Upper Mississippi River since record keeping began in the late 19th century. A classification scheme regarding the occurrence and relative distribution of fish was developed by Rasmussen (1979). A distributional atlas was organized by Smith et al. (1971).

Studies of the Illinois River have illustrated a general deterioration of fish, both in numbers of species and in condition of certain of the fish studied. This deterioration has been concommitant with a loss of aquatic vegetation.

Vertebrates other than fish were the subject of a 1977 report by the U.S. Army Corps of Engineers. Recent, generalized faunal changes for the navigable reaches of the Upper Mississippi River System include: (i) an increase in deer populations and decrease in squirrel populations in bottomlands; (ii) an increase in wood duck populations in bottomlands; (iii) decline in bald eagle populations; (iv) a reduction after impoundment of meadows, which adversely affected species such as quail and shorebirds; (v) a reduction in sandbar nesting habitats for turtles; (vi) a reduction in habitats for racoon, groundhog, and rabbit due to clean farming practices; (vii) an increase after impoundment in marsh habitats for fur bearers; (viii) a great increase in waterfowl usage due to a rise in aquatic plant productivity after impoundment; and (ix) an unaccounted-for recent decline in wading birds, such as the great blue heron, great egret, and black-crowned night heron.

AQUATIC AND TERRESTRIAL HABITATS

Biologists of the Upper Mississippi River Conservation Committee (UMRCC) developed a habitat classification scheme for the prupose of the study and management of fisheries (Sternberg, 1971). The classification scheme incorporates general factors that affect the quality of fisheries habitat. It employs a standardized nomenclature that replaced local conventions which hindered communication through the application of different names for similar habitats. The classes of the scheme are, in addition, commonly used to organize the presentation of research on organisms other than fish. The following descriptions of the UMRCC habitats are taken directly from Sternberg (1971), except for the format of the one literature citation (Hutchinson, 1957).

Main Channel

This includes only the portion of the river through which the large commercial craft can operate. It is defined by combinations of contraction works (wing dams), river banks, islands, and bouys and other markers. It has a minimum depth of 9 feet and a minimum width of 300 feet. A current always exists, varying in velocity with water stages. The bottom type is mostly a function of current. The upper section usually has a sand bottom, changing to silt over sand in the lower section. Occasional patches of gravel are present in a few areas. Most of the main channel is subject to scouring action during periods of rapid water flow and by passage of towboats in the shallower stretches. No rooted aquatic vegetation is present.

Main Channel Border

This is the zone between the 9-foot channel and the main river bank, islands, or submerged definitions of the old main river channel. It includes all areas in which wing dams occur along the main channel. This area is commonly thought of as being part of the main channel, but for fisheries purposes it is considered as a separate habitat. Buoys often mark the channel edge of this zone. Where the main channel is defined only by the bank, a narrow border still occurs, and often the banks have riprap and fair to good fish habitat. Dredge spoil has been placed in some sections of this zone, sometimes convering wing dams. The bottom is mostly sand in the upper sections of the pools and silt in the lower. Little or not rooted aquatic vegetation is present. This zone provides some of the better fishing along the river at certain times of the year.

Tail Waters

These include the main channel, main channel border, and the areas immediately below the dams which are affected in turbulence by the passage of water through the gates of the dams and out of the locks. Since these areas change in size according to water stage, an arbitrary lower boundary for fishery

purposes has been set at a distance of one-half mile below the dams. The bottom is mostly sand. No rooted aquatic vegetation is present.

Side Channels

These include all departures from the main channel and main channel border, in which there is current during normal river stage. The gradations in this category are widespread, ranging from fast flowing watercourses with high banks to sluggish streams winding through marshy areas. Unless they are former main channels (a situation occurring in a few places on the Mississippi), the banks are usually protected. Undercut or eroded banks are common along side channels near their departure from the main channel. This occurs mainly in the upper sections of the pools where banks are highest and the current is swifter. Closing or diversion dams are usually present where the side channel leaves the main channel or main channel border, and infrequently at other locations. In the impounded section of the river, these are mostly submerged. The bottom type usually varies from sand in the upper reaches to silt in the lower. In the swifter current, there is no rooted aquatic vegetation, but vegetation is common in the shallower areas having silty bottoms and moderate to slight current.

Other terms that have been used for this habitat are sloughs, running sloughs, chutes, cuts, guts, cut offs, and canals.

River Lakes and Ponds

In connection with this classification, broadly speaking, the term "backwater" is no longer used. This is now incorporated in the lake and pond category, or in the following and final category termed "sloughs". Most lakes and ponds in the Mississippi River bottoms are adequately defined by Hutchinson (Hutchinson, 1957). Following are the types assigned, with definitions. Examples of these types occurring along the Mississippi are given.

Lakes of formation due to fluviatile dams:

Type 49 - (Lake Pepin, between Minnesota and Wisconsin).

Lakes of mature flood plains:

Type 55 - Oxbows or isolated loops of meanders (Spring Lake near Buffalo City, Wisconsin).

Type 56 - In depressions formed on flood plains (Sturgeon Lake in Minnesota).

Type 57 - Between natural levee and scarp (Goose Lake in Wisconsin).

Lakes due to behavior of higher organisms:

Type 73 - Dams built by man (Keokuk Lake between Iowa and Illinois. Large open areas, usually not named, off the main channel and main channel borders just above many of the dams).

Refer to Hutchinson for further detail and description of river lakes and ponds.

In river studies on the Mississippi, only those lakes having some connection with the river during normal water stages are usually considered. River lakes and ponds may or may not have a slight current, depending on their location. Type 49, for example, has some current, especially in the upper and lower extremities. Most of the bottoms are mud or silt, often consisting of a layer two or more feet thick. These waters may have an abundance of rooted aquatic vegetation, both submerged and emergent. They may be surrounded by marshland.

Sloughs

This category includes all of the remaining aquatic habitat found in the river. Sloughs often border on the lake or pond category on the one side and on the side channel category on the other. They may be former side channels that have been cut off, or that have only intermittent flows in them. They may be relatively narrow branches or off shoots of other bodies of water. They are characterized by having no current at normal water stage, muck bottoms, and an abundance of submerged and emergent aquatic vegetation. These sloughs and some of the ponds and smaller lakes are most often representative of the ecological succession taking place in the river bottoms, from aquatic to marsh habitat.

Another term that has been used for this category is "dead slough".

The geographic distribution of the UMRCC aquatic habitats, along with the major processes that have affected and are affecting the habitats, is the topic to which the discussion presently turns. Much of the following discussion is concerned with the distribution of the habitats in terms of physical dimensions. Terrestrial and aquatic vetgetation, the latter of which is an integral part of the quality of an UMRCC habitat, are discussed in a general fashion concurrently with the discussion of UMRCC habitats in order to provide a perspective on the broad characteristics of the rivers and their reaches (see also AQUATIC AND TERRESTRIAL VEGETATION).

Information Sources

Recent measurements of the spatial distribution of some of the preceding aquatic habitat types and of general floodplain cover types are available for a major portion of the Illinois Waterway (Bellrose et al., 1977; USAED, SL, 1980), the Upper Mississippi River, the lower St. Croix, and lower Minnesota River (Minor et al., 1977; Hagen et al., 1977; Olson and

Meyer, 1976a). Air photo interpretation was utilized to ascertain the low-stage water and land characteristics of the Mississippi, Minnesota and St. Croix River. The photos of the Mississippi reach from Pool 3 to the Ohio River were taken in 1975, while the photos of Pool 1 and 2, and the Minnesota and St. Croix River were taken in 1973. A variety of information sources, dating from the late 1960s to mid 1970s, was employed for the Illinois Waterway. The Illinois Waterway data are used herein as published, except for some aggregation of data categories; the treatment of the information for the other streams follows, when possible, a previous treatment of these same data in the reach from Pool 11 to 22, Mississippi River (GREAT II, FWWG, 1980). Quantitative habitat data were not found for the lower Kaskaskia River. The water and land classification schemes for the above studies are given in Appendix A.

The figures presented for Pool 4 in the aforementioned 1975 remote sensing assessment (Minor et al., 1977) do not include a large reach of Lake Pepin. Figures for this excluded reach were obtained from a 1973 remote-sensing study (Olson and Meyer, 1976a; or Olson and Meyer, 1976b) and were combined with the available 1975 figures to form Pool 4 totals. By incorporating the 1973 data, the water surface area of Pool 4 is moved from a rank of fifth to a rank of first among the Mississippi River pools.

The main channel category of two remote-sensing studies, which together cover the Mississippi from Pool 3 to Cairo, is a combination of three UMRCC classes: main channel (that is, the nine-foot commercial navigation channel), main channel border, and tail water (Minor et al., 1977; Hagen et al., 1977). An area figure was provided for the commercial navigation channel by taking the channel to be 450 feet in width. The remainder of the remote-sensing main channel category was assigned to the main channel border class. Tail water, which is relatively small in areal extent and has a well-known location, is subsumed under the other two main channel classes. For Pool 1 and 2, and the lower Minnesota and lower St. Croix, a single main channel category was formed from the available main channel classes, and the preceding method was applied to derive the areas of the commercial navigation channel and main channel border.

The definitions utilized in the remote-sensing classification schemes for the non-channel habitats (lake, pond, slough) were not sufficiently similar to the respective UMRCC definitions to warrant the presentation of area figures for the habitats separately. When all non-channel classes of the UMRCC and remote-sensing studies are aggregated, a single non-channel category is formed. A better estimate of the aggregation of the UMRCC non-channel classes was derived from the remote-sensing data by adding areas of free-floating (duckweeds--Lemnaceae) and submergent aquatic vegetation to the remote-sensing aggregation of non-channel open water (Minor et al., 1977; Hagen et al., 1977). The addition of those vegetation areas was done because open water in the remote-sensing studies is defined as not supporting visible growths of vegetation, and the visible growths of free-floating and submergent aquatic vegetation are concentrated in non-channel waters. Floating-leaved aquatic plants were combined with emergent aquatics (marsh). The life form of a plant (e.g. emersed, submersed) was identified by dominant species or genus

(see Appendix A). The following open water classes are eventually used for all streams: commercial navigation portion of main channel (that is, the UMRCC main channel category), main channel border, side channel, and non-channel. Tail water is used only for the Illinois Waterway.

A few of the floodplain classes from two of the remote-sensing works were altered slightly in order to achieve greater class consistency. The "developed grass" category of the study that covers the lower reach of the Mississippi River (Pool 11 to Cairo - Hagen et al., 1977) was moved to the terrestrial herbaceous class, because it was largely levee grass for much of the lower reach (GREAT II, FWWG, 1980), and levee grass is placed in terrestrial herbaceous in the upper reach (Pool 3 to 10 -- Minor et al., 1977). The "grazed meadow" category of the study that covers the upper reach was shifted to the agriculture class, because it is placed in agriculture in the lower reach. "Dredge materials" in the study of the lower reach were combined with their associated vegetation or land cover types. Areas of dredge materials are so categorized in the work that covers the upper reach. The floodplain classes for Pool 1 and 2, and the lower St. Croix and the lower Minnesota River were matched as closely as possible to the classes utilized for the bulk of the Mississippi (matchings given in Appendix A). The available classes for the Illinois Waterway are presented without change.

In the remote-sensing studies that cover the Mississippi, St. Croix, and Minnesota River, the area inventoried as the "floodplain" was usually defined as the unprotected floodplain that experiences frequent, if not annual, inundation. This area was, however, extended at times to include land that experiences less frequent flooding and that is protected from the river by levees (Minor et al., 1977; Hagen et al., 1977; Olson and Meyer, 1976a). There was in other words, no unambiguous definition of the land to be inventoried. For the Illinois Waterway above La Grange dam, the inventoried land area extends to the forest line that preceded the completion of the nine-foot channel project (Bellrose et al., 1977). So delineated, this part of the Illinois land inventory covers a considerably smaller land area than was incorporated into the inventory of the Mississippi River. The inventory of the Alton pool of the Illinois River, on the other hand, contained a relatively large expanse of terrestrial cover (USAED, SL, 1980).

Present Distributional Patterns

Mississippi River

Long reaches of the Upper Mississippi River have similar characteristics in terms of general aquatic classes and general land cover types. The reach above Lock and Dam No. 13 (L & D 13) has (1) a relatively large absolute amount of water surface area that is off the main channel (Table 1), (2) a comparatively large proportion of water surface area in the non-channel class (Figure 2), and (3) a sizable absolute (Table 1) and relative (Figure 3) cover of floating-leaved aquatic and marsh vegetation. Downstream of L & D 13, the sum of the main channel and main channel border class progressively comprises a greater proportion of total open water.

In the open (unimpounded) river, the main channel and main channel border account for over eighty percent of the water surface. Land cover (non-open water) below L & D 13, compared with the cover above L & D 13, shows a decrease of floating-leaved aquatic and marsh vegetation and an increase of woody and agricultural land (Table 1 and Figure 3). The absolute coverage of floating-leaved aquatic and marsh vegetation is particularly small in Pool 15, 20, 21 and 22. The floodplain of the open river is utilized extensively for agricultural purposes, and floating-leaved and marsh vegetation are not abundant in the open river.

The principal exceptions to the preceding broad characterizations occur in Pool 4, which is dominated by Lake Pepin, and in the urban concentrates of the Quad Cities (Pool 15) and the Twin Cities (Pool 2). Pool 1, also in the Twin Cities, is distinct from other pools. The river in Pool 1 is constrained within a narrow gorge that was created by the upstream retreat of St. Anthony Falls. The floodplain in the gorge is quite small, and lakes and sloughs are not found in Pool 1. The gorge extends into the upper reaches of Pool 2. It should be noted that much of Keokuk Lake (Pool 19), an artificial river lake, has been classified as main channel border, which accounts for the large area of the main channel border class in Pool 19.

The rather abrupt change in the general diversity of water classes between the open (unimpounded) and pooled (impounded) river reach is due largely to the different stream improvement techniques that have been utilized on the two reaches to maintain channel depths for navigation. The navigation channel of the open river has historically been maintained principally by dredging and wing dikes. Wing dikes radiate out into the river from a bank, and are designed to concentrate the flow in the navigation channel and to reduce the flow elsewhere. Flow-concentration increases river velocities and bed scouring in the navigation channel, whereas the drag of the dikes causes sedimentation in the main-channel border locations of the wing dikes. Over time, water of the main channel border has been transformed into dry land. The average width of the Middle Mississippi (the reach between its confluence with the Missouri and Ohio River) has been reduced forty percent since the late 1800s (Mueller, 1977). Superimposed on the influences of wing dikes are the additional "river training" effects of closing dams and bank protection. These anthropogenic controls over the course of the river effectively preclude the natural creation of new side channels and backwaters (Rasmussen, 1979). Overall, the historical trend in the appearance of the open river has been toward a deeper, narrower, more rock-lined channel, with a greater paucity of off-channel aquatic and wetland habitat (Rasmussen, 1979).

The unimpounded river, compared with the impounded river, tends to be a less favorable setting for aquatic and marsh vegetation. The primary factors that account for the less favorable setting are a lack of low velocity (off-channel) waters, wide fluctuations in water surface elevations, and a high turbidity and sedimentation rate (Rasmussen, 1979). The Missouri River has traditionally been a major, external contributor to the turbidity and sediment load of this reach of the Mississippi River. Internal contributions to the turbidity and sediment load are made by the scouring action of the channelized flow and by the frequent, large-scale dredging activities for channel maintenance (Rassmussen, 1979).

Whereas the navigational improvement practices of the unimpounded river constricted water surface area, the impoundment of the river for the nine-foot navigation channel raised normal low-water levels the requisite amount, thus inundating former islands, side channels, and large tracts of the low-lying floodplain. The earlier six-foot navigation channel in this presently pooled reach was maintained as the open river is today, that is, principally with wing dikes and dredging. Dredging remains an important channel maintenance practice. Most of the six-foot channel wing dikes were submerged when the pools were flooded.

An example of the early effects of impoundment on land and water habitats, and of the changes since impoundment is available for Pool 5 to 10 (Figure 4 — the pools of Figure 4 were flooded during the period from 1935 to 1938). The basic pattern of net changes in land and water habitats from pre-impoundment to the 1970s that was experienced in Pool 5 to 10 (Figure 4)was also experienced over the impounded Mississippi River as a whole (Figure 5). Early post-impoundment data were only found for the reach from Pool 5 to 10.

The most salient result of impoundment was the gain in water surface area and the concomitant loss in land area (Figures 4 and 5). Nearly all of the water area increase occurred in the non-channel class, while the increase in the main channel and side channel classes was small by comparison. The growth in water surface area was experienced with varying magnitudes along the river. The magnitude of water area expansion above Dam 13,compared with the pooled reach below, was generally large (Olson and Meyer, 1976a; USAED, 1977; USAED, SL, 1980), a fact that is evident in the present spatial distribution of non-channel waters (Table 1).

In conjunction with the growth of non-channel (slack-water) surface area, the stabilization of low-water levels had a pronounced influence on the distribution and productivity of aquatic vegetation (Green, 1970— Green's qualitative observations refer to the Upper Mississippi River Wildlife and Fish Refuge, which stretches from the Chippewa River in Pool 4 to Pool 14 and includes the pools of Figure 4). New site opportunities for aquatic vegetation were created when the slack-water area was expanded by the permanent rise in low-water levels. The new opportunities, however, were achieved at the expense of the eradication of some of the former aquatic vegetation, which was covered too deeply for survival by the stabilization of low-water levels above pre-impoundment levels. Low-water level stabilization also diminished the magnitude of water level fluctuations, whose size limited the sustained productive of aquatic macrophytes during pre-impoundment times (Green, 1970). The sum of the gains and losses in the coverage of marsh vegetation between pre-impoundment (ca. 1929) and early post-impoundment (ca. 1939) was, according to the data of Figure 4, negligible. The relatively large increase of marsh occurred between the survey dates of ca. 1939 and 1973, with approximately this same magnitude of increase occurring between ca. 1929 and 1973.

Consistent with the reach from Pool 5 to 10 (Figure 4), the impounded Mississippi River as a whole experienced a gain in marsh coverage from pre-impoundment to the 1970s (Figure 5). The largest increases in marsh were generally experienced in the upper river, especially above Dam 13,

where there was a relatively large coverage of floating-leaved aquatic and marsh vegetation in 1975 (Table 1--Olson and Meyer, 1976a; USAED, 1977; USAED, SL, 1980). Pool 15, 20, 21 and 22 had only minor coverages of marsh in the pre-impoundment survey, experienced small changes in marsh between the pre- and post impoundment survey, and contained only minor coverages of floating-leaved aquatic and marsh vegetation in 1975 (Table 1--USAED, 1977).

In addition to expanding water surface area, impoundment diminished the annual range of water surface elevations. Spring floods still achieve the high elevations of pre-impoundment times, but low-water levels are maintained above pre-impoundment levels by the operation of the navigation dams. The annual water-level range is smallest just above the dams and progressively increases upstream to the base of the next dam, where the range most closely approximates that of the pre-impoundment period. This intra-pool pattern of annual water-level ranges is the basis upon which Green (1970) divided pools, in general, into distinctive vegetational zones. A quantitative example of Green's qualitative observations is selected from low-water Pool 9 data, which seem to fit Green's observations quite well (Table 2). Pool 9 water/land historical changes are virtually identical to those for the reach from Pool 5 to 10 (Figure 4).

According to Green, in the upstream reach of each pool the comparatively large annual range of water-level fluctuations limits marsh development (Green, 1970). Vegetation communities of this part of the pool are at the dry end of the spectrum of communities that inhabit the local river environs (Table 2). The exposure of the large tracts of bottomlands during the summer drawdown is probably an important reason for the concentration of terrestrial herbaceous vegetation in the upper reach of the pool. In the downstream reach of the pool, just above the dam, impoundment created persistently deep water, which restricts marsh developmemt (Green, 1970). Progressing upstream from the dam, impoundment flooded a progressively smaller amount of the former floodplain, the depth of the low-water flooding decreases, and the range in water-level fluctuations increases. It is toward mid-pool where the functionally related factors of land area flooded, depth of flooding, and degree of water-level stabilization created the best marsh development (Green, 1970).

Impoundment provided new site opportunities for aquatic vegetation. The new opportunities were created over flooded tracts of meadows and woods, producing a rapid decline in coverage of these two vegetation types from pre-impoundment to early post-impoundment (Figure 4). The meadows of pre-impoundment times were the result of: natural factors, which helped to select meadows through seasonal flooding and drying of the river bottoms; of anthropogenic factors, which maintained some of the land classified as meadows for pasturage and hay; and of a combination of human and natural factors, which maintained a high incidence of fire in the seasonally dry, grassy meadows (Olson and Meyer, 1976b). Meadows were reduced by impoundment. Impoundment permanently flooded some meadows, decreased the amount of land annually inundated and dried, and helped to reduce the level of agricultural activity on the floodplain. Secondary succession to forest reduced the size of the unflooded meadows; forests also spread onto

agricultural lands abandoned subsequent to pool formation (Olson and Meyer, 1976b). Urban land was the only category to illustrate a monotonic increase from the earliest to latest survey data (Figure 4). The urban development, in this example, was mostly due to the expansion of bottomland cities into the inventoried land area (Olson and Meyer, 1976b).

Pre-impoundment to 1970s land cover and land use changes for Pool 5 to 10 (Figure 4) are consistent with those for the impounded Mississippi River as a whole (Figure 5). Woody vegetation has approximately the same coverage in the pre-impoundment and 1970s survey, urban land has increased, and meadows and agricultural land have decreased sharply (Figure 5).

The 1920s survey that describes pre-impoundment conditions for other pools occurs after the flooding of Pool 1 and Pool 19, both of which were impounded prior to 1920. Between the 1920s and 1970s survey, Pool 1 changes have been small (Olson and Meyer, 1976a), while the major changes in Pool 19 have been a decrease in water surface area and marsh, a decrease in meadow and agricultural land, and an increase in woody vegetation and developed land (USAED, 1977).

From the time of impoundment, water surface area declined (Figure 4), as silt accumulation reduced the storage capacity of backwater lakes and sloughs (GREAT I, SEWG, 1980). The filling of backwater lakes and sloughs is a process affecting the entire pooled reach of the river (GREAT I, SEWG, 1979; GREAT II, SCWG, 1980; Sparks et al., 1979). Impoundment created hydraulic conditions conducive to sedimentation, for it expanded the cross-sectional area and reduced the velocity of the river, thereby lessening sediment transport capability. Furthermore, the increase in water depths resulting from impoundment represents an added potential for increased sedimentation, because the potential quantity of suspended sediment for deposition is proportional to, at a given suspended sediment concentration, the depth of the water. Due to this relationship between water depth and the potential rate of sedimentation, when backwaters are actually filled by sediment, water volume decreases at a more rapid rate than water surface area (Bellrose et al., 1979). The differential rate of depth-dependent sedimentation transforms backwaters, with relatively steep bottom gradients, into areas of shallows of largely uniform depth. Some of these newly created shallows may be colonized by aquatic and marsh vegetation (Olson and Meyer, 1976b); the continued filling of shallows will promote succession to terrestrial vegetation. Sedimentation, in conjunction with its associated effect on turbidity, has led to the eradication of many aquatic and marsh vegetation beds on the Illinois River (Mills et al., 1966). Sparks et al. (1979) present evidence suggesting that sedimentation and its attendant turbidity have recently begun to affect adversely aquatic and marsh vegetation in the lower pooled reach of the Mississippi River.

The rapid rate at which fine sediment has accumulated in the backwaters, and at which it continues to be generated in the drainage basin raise concerns over the future of these important biological habitats (e.g., GREAT I, FWWG, 1979; GREAT II, SCWG, 1980). As the pools fill with sediment, new water areas off the main channel are not being formed by natural forces (GREAT II, SCWG, 1980). Even if the artificial expanses of water created by pool formation were to be lost, the river environment

would not approach that of the pre-impoundment period because of the increase in human control over the course of the river since pre-impoundment times (GREAT II, SCWG, 1980). The problems surrounding the question of siltation will be a recurring topic in this report due to the pervasive biological effects of siltation. What will not be addressed here is the important set of problems resulting from agricultural soil erosion, the primary source of fine sediment in the drainage basin.

Illinois Waterway

The completion of the nine-foot navigation channel was one, among several, of the historical factors that has materially altered the distribution of water and land along the Illinois Waterway in this century. The first salient alteration, commencing in 1900, was the diversion of Lake Michigan water, along with Chicago-area sewage, into the Illinois River System via the Chicago Sanitary and Ship Canal. The magnitude of the diversion became sufficiently large by the 1920s to dramatically increase the area of lakes, marshes and sloughs of the Illinois River (Bellrose et al.,1979). As the Lake Michigan diversion increased in the first two decades of the century, agricultural levee and drainage districts proliferated in the valley bottoms. Extensive tracts of bottomlands were drained and protected. Some areas were found to be marginal for agriculture and were allowed to revert to their previous status as open water and marshes (Bellrose et al., 1979).

During the 1930s the nine-foot channel project was completed. The project was finished above Starved Rock lock and dam in 1933, at a time when the quantity of water diverted from the Lake Michigan watershed was still relatively large. Below Starved Rock lock and dam, the nine-foot channel was completed in 1938, and the completion date was coordinated with a sizable drop in the quantity of the Lake Michigan diversion (Bellrose et al., 1977).

The Lake Michigan diversion, completion of the nine-foot channel project, agricultural activities, and one additional factor, sedimentation, have all been major contributors to the changes in land and water areas that were assessed between a survey pre-dating completion of the nine-foot navigation channel and a survey in the late 1960s or 1970s (Bellrose et al., 1977; USAED, SL, 1980). Between the two surveys, the aggregate change in water surface area was an increase of sixteen percent (Figure 5). As parts of the aggregate gain, each pool showed an increase. The short pools above Peoria pool, which are located in the reach of the river with a comparatively steep bottom gradient, experienced the largest relative gains in water surface area, but the smallest absolute gains. The reach from Peoria pool to the mouth of the river can be characterized, before and after the completion of the nine-foot navigation channel, by sizable expanses of bottomland lakes (Table 3).

The completion of the nine-foot channel, in conjunction with the drop in Lake Michigan diversion, increased sedimentation by lowering river velocity (Bellrose et al., 1977). The general effects of sedimentation and its associated turbidity, plus some local effects of manipulated water-level increases, have taken a heavy toll on the marsh vegetation of the Illinois River (Table 5--Bellrose et al., 1979; Bellrose et al., 1977). The

recent marsh figures of La Grange and Peoria pools (Table 3) are approximately one-third and one-fourth the size, respectively, of the figures for the pre-nine-foot channel project survey (Bellrose et al., 1977). Above Peoria pool, the change in marsh between the survey dates is positive for only the Dresden Island pool, and the aggregate change above Peoria pool is a decrease of approximately two-thirds. The aggregate decrease above Peoria pool is attributed to the initial flooding of former marsh areas by the raised low-water levels for the nine-foot channel, and the lack of subsequent marsh development (Bellrose et al., 1977). For the Alton pool, the decrease in marsh coverage between the survey dates was a comparatively small twelve percent (USAED, SL, 1980).

The land inventory for the Alton pool was larger than for other pools (Table 3), and it dominates the pre-project to 1970s changes displayed in Figure 5. For the Alton pool, woody and agricultural coverage have experienced slight declines, and urban land has increased (USAED, SL, 1980). Woody land was expanded considerably in La Grange and Peoria pool by the filling of bottomland lakes with sediment (Bellrose et al., 1977). In contrast, woody land in the inventoried area above Peoria pool was nearly eradicated by the raised water levels for the nine-foot navigation channel (Bellrose et al., 1977). Agricultural land in the inventoried area above Alton pool has either increased or decreased, depending on the pool, and urban land has illustrated an aggregate increase (Bellrose et al., 1977).

Minnesota and St. Croix River

Dam closures along the Mississippi River had little effect on the changes in water surface areas of the lower Minnesota and lower St. Croix River from the late 1920s to early 1970s (Olson and Meyer, 1976a). The St. Croix River had only a small expanse of marsh flora in the late 1920s, as was the case in the early 1970s (Table 3--Olson and Meyer, 1976a). Marsh coverage in the lower Minnesota River was approximately ten percent smaller in the early 1970s than in the late 1920s (Table 3--Olson and Meyer, 1976a). The lower Minnesota has experienced a decrease in agricultural land and meadows, and an increase in woody and developed land since the 1920s (Olson and Meyer, 1976a). The expansion of developed land in the lower Minnesota River was partly due to the general growth of the Twin Cities and partly due to the construction of port facilities (Olson and Meyer, 1976b).

Kaskaskia River

A nine-foot navigation channel was authorized by Congress in 1962 for the reach of the Kaskaskia River from its confluence with the Mississippi River to Fayetteville, Illinois (USAED, SL, 1975). A quantitative survey of the aquatic and terrestrial habitats that either pre- or post-dates the navigation project was not found, although qualitative observations on some of the gross effects of the project are available in the literature.

The lower 18 miles of the river were prepared for commercial navigation by channelization, while the reach from mile 18 to Fayetteville was prepared by canalization (USAED, SL, 1975). The navigation project shortened the sailing distance to Fayetteville from 50 miles to 36 miles. Channel-

ization involved widening, deepening, and straightening the original channel where needed. Canalization created a relatively straight, artificial navigation channel. Stream meanders were cut off and were plugged at their upper ends, producing habitats somewhat similar to backwaters. Other habitats, such as deep pools, gravel bars, log jams, and bank vegetation,were eradicated by the project in certain reaches (Larimore, 1978).

Sedimentation may be a significant problem for the quality of channel and off-channel habitats in the project area (Larimore, 1978). A navigation dam, located less than one mile upstream from the mouth of the river, will augment sedimentation potential by increasing the depth of the water column from which sediment can precipitate out, and by decreasing river velocity (Larimore, 1978). Bank erosion may be large in the project area, because some river banks were destablized by dredging and vegetation removal, and because dredged material has been deposited on the banks (Larimore, 1978).

BENTHIC MACROINVERTEBRATES

Mussels

Mussel Inventories

Mussel inventories on the Upper Mississippi and the Illinois River are based on a considerable number of collections and surveys made during the 20th century. Noteworthy among these studies are the works of Baker (1903), Grier (1922), Grier and Mueller (1922-23), Dawley (1947), van der Schalie and van der Schalie (1950), Stansbery (1970), Starrett (1971), and Fuller (1978). Numerous additional studies have focused on particular segments of these water bodies.

This report summarizes the collections from the Mississippi, Minnesota, St. Croix and Illinois River in two categories: (a) 1964 and before, and (b) post-1964. The results are given in Tables 4 and 5. During the years 1964 and earlier, 46 mussel species were known from the Mississippi River. Post-1964 studies show 43 species. It must be regarded that post-1964 surveys, e.g. Fuller (1978), are as extensive as the earlier work and, thus, that the decline in species numbers is probably real. However, despite factors which doubtless have adverse effects on mussel populations, the Mississippi River and some of its tributaries remain among the world's prime mussel habitats.

In the Mississippi River, certain areas have received greater attention than others. Pools 4, 5, 6, 10 and 16 have been subjects of numerous investigations and thus probably present a more accurate assessment of the current status of mussel populations. However, the uneveness of study efforts has been largely alleviated by the work of Fuller (1978), which encompassed most of the Upper Mississippi River.

Surveys show a paucity of mussel fauna in the upper reach of the commercially navigable Mississippi. Thirteen species occurred in Pool 2 prior to 1964, and nine species have been found in post-1964 studies. Pool 1 and Upper St. Anthony Falls Pool are devoid of mussels, whereas Lower St. Anthony Falls and Pool 3 were not sampled post-1964, although the area probably once contained a rich naiad fauna. Destruction of the mussel populations occurred long before intensive channel maintenance; thus the poor mussel fauna of this region is likely due to poor substrate and ecological adversity that have been extant for many years (Fuller, 1978). The mussel fauna of the lower Minnesota River was devastated long ago, probably due to agricultural runoff and also to biocides. In fact, the pollutants from the Minnesota River may well be responsible, along with pollutants from the Twin Cities, for the damage to mussels in Pools 2 and 3 of the Mississippi River.

Pool 4, which includes Lake Pepin, once contained 39 species of mussels, including the endangered Lampsilis higginsi and Proptera capax (see Dawley, 1947; and van der Schalie and van der Schalie, 1950). In post-1964 studies, the number of species had been reduced to 20, and the endangered species were not found. In 1977, Fuller found but 12 species in this pool. In all likelihood, the decline in mussels from Pool 4 was a real trend and

was not due to an incompleteness of surveys. Pool 4 has received considerable attention in recent as well as in earlier surveys, but the extensive Lake Pepin may still harbor mussel communities heretofore unknown. Some pertinent facts emerge, however. First, the decline in mussel populations parallels the increasing efforts at channel maintenance. Secondly, the decline in mussel populations is concurrent with the expansion of the human population and the human contributions (e.g. agricultural runoff) to the Mississippi River. With regard to the former, dredging is intensified in lower reach of Pool 4 because of the deposits from the Chippewa River. Also, because of these deposits, it is ascertained that sections of Pool 4 are unsuitable for mussels. Hence, the factors that create problems for navigation also do so for mussels (Fuller, 1978). Because Lake Pepin functions as a large catch basin for contributions from upstream agricultural and urban populations, and because the mussel fauna of this waterbody shows considerable evidence of damage, Lake Pepin must be regarded as a critical area in which continued surveillance is imperative.

The St. Croix River, which joins the Mississippi at the upper reach of Pool 3, apparently harbors a healthy mussel fauna, although sampling has been limited. It would be expected that the St. Croix would contribute in a positive way to the quality of Pool 3. It is noteworthy that the endangered Lampsilis higginsi, not presently found in Pools 3 or 4, has been recently collected from the St. Croix (Fuller, 1978).

Compared with Pool 4, the mussel population of Pool 5 seems to be in a more healthy state. In terms of numbers of species, there does not seem to be much difference in the two pools (Table 5), but Fuller (1978) recorded a greater number of individuals per brail run in Pool 5. Further, Fuller (1978) noted a predominance of juveniles of Truncilla donaciformis in Pool 5, although his sampling was selective for that species.

Pools 6 and 7 have not been subject to extensive survey work in recent years, so it is difficult to determine whether or not the populations compare favorably with mussel communities studied earlier. The endangered Lampsilis higginsi was reported from Pool 7 in 1965 (Finke, 1966). Information regarding Pool 8 is tempered by a paucity of historical records. The survey of Coon et al. (1977) for Pools 8, 9 and 10 allows a comparison with a 1930-31 survey (van der Schalie and van der Schalie, 1950). Although there is a loss of some species (noteworthy are the endangered Lampsilis higginsi and Proptera capax) from parts of this three-pool segment, whether real or artifactual, the records show the mussel fauna of Pools 8, 9 and 10 to be in reasonably good condition. However, a close look at Pool 9, based mainly on the data of Fuller (1978), shows that Amblema plicata was the most abundant species, accounting for just over fifty percent of the total individuals. Fusconaia flava, the second most abundant species, accounted for eight percent of the mussels from this pool. No other species represented more than seven percent of the unionid fauna. Amblema plicata is one of the mussels known to be quite tolerant of adverse conditions. This species has been known to survive for extended periods of time in the absence of oxygen (Imlay, 1971) and to be tolerant of muddy bottoms and of other conditions associated with impoundment (Imlay, 1972). Since Amblema plicata represents a substantial part of the mussel fauna of the Upper Mississippi (Table 6), it must be considered that the entire mussel fauna may be in a more fragile state than may at first be apparent.

Pools 10 and 11 are species-rich (Table 5). Pool 10 apparently is in a stable condition, whereas it is difficult to judge the current situation in Pool 11 because of the lack of pre-1964 data. It would seem, however, that the mussel fauna is healthy. Likewise, most survey work in Pool 12 is based on recent studies (Davis and Cawley, 1975; and Perry, 1979), which seem to indicate thriving mussel populations.

Pools 13, 14, 15, 16 and 17 have been recently surveyed (Perry, 1979; Fuller, 1978) and show an apparently healthy mussel fauna. However, comparisons with earlier studies are difficult, especially in Pools 14, 15 and 17, because of the scarcity of pre-1964 data. Lampsilis higginsi occurs in Pools 14 to 17 as does the rare Fusconaia ebena. Tritogonia verrucosa and Plethobasus cyphus, both rare in the Mississippi, occur in Pools 16 and 17. Fuller (1978) commented that "...the unusually large number of Quadrula metanevra, a rarity, is a positive reflection upon environmental quality here (in Pool 17)." Information regarding specific sites shows that not all sites are uniformly hospitable, however. The effect of dredge spoil at a site in Pool 16 was reported by Fuller (1978):

> An encouraging feature of this site is the diversified and rather individual-rich naiad population that swells in the gravel beneath about 10 feet of water immediately below the Centennial Bridge. This population has thrived through decades when dredged material was cast loose upon the shore only yards away. The implication is that decay of this "spoil bank" has done the adjacent mussel bed little or no harm.

However, Fuller continued with a description of a nearby site:

> Opposite this bank and just off the Iowa shore there is an extensive area of muddy streambed that is strewn with major trash (bicycle frames, hoop nets, etc.). Here were taken fewer mussels, and these were dominated by a single species, Amblema plicata. This population contrasted sharply with the previous one and may partly counter Kaskies' (1971) contention about mud being the most suitable streambed for mussels.

Pools 18 and 19 seem to compare favorably with earlier findings. Only the rare Fusconaia ebena and Strophitus undulatus, both recorded from early surveys, were absent in post-1964 collections from Pools 18 and 19. Cumberlandia monodonta, on the other hand, was not found pre-1964, but was recorded in post-1964 collections. Pools 20 and 21 are comparatively poor both in numbers of individuals and species (Fuller, 1978). The Des Moines River enters Pool 20 and probably has an adverse effect on mussel fauna. It is thought that the Des Moines River contributes considerable quantities of sand, urban pollutants, and agricultural runoff to the Mississippi River. The contribution of sand would compound any effects that dredging might have. Apparently, the Des Moines River has not been the subject of a recent extensive study of mussels or other benthic invertebrates. Because of the relatively pool mussel fauna of Pools 20 and 21, an assessment of the impact of the Des Moines River should be

made. It would appear that Pools 20 and 21 should be regarded as transitional habitats, and careful monitoring of this river segment should be warranted.

Pool 22 to the confluence of the Ohio River has not been studied, either historically or in recent times, as extensively as most of the pools upstream of Pool 22, so the data are less meaningful. The rare Fusconaia ebena and Tritogonia verrucosa,as well as the endangered Proptera capax, have been recorded from this stretch pre-1964, but the status of these species at the present time is not known. Also, it would be expected that the impact of the Des Moines River might be felt for at least a portion of this segment. Clearly, additional survey work needs to be done here.

The Illinois River was once considered to be the most productive mussel stream per mile in this country (Danglade, 1914). A thorough and valuable contribution by Starrett (1971) permits a good assessment of the current state of the mussel populations from this river. Though parts of the Illinois River once harbored as many as 39 species of mussels (Table 5), present species counts are only about one-half of that number. The most common mussel from the Illinois River is Amblema plicata, which represents 62.4 percent of all mussels collected (Table 6). Other common species are Quadrula pustulosa, Quadrula quadrula, Megalonaias gigantea, and Anodonta grandis corpulenta. The extirpation of mussel species was considerably more drastic in the upper than in the lower segments of the river (Table 5). Domestic and industrial pollution have doubtless been the major factors that have adversely affected mussel populations and, in some instances, siltation has also played a major role. It must be remembered that the decline of mussel populations and species in the Illinois River has been a process that has surely occurred throughout this century. For example, by 1912 pollution had virtually wiped out the mussels from the upper navigation pools of Starved Rock and Marseilles. In 1966, no living mussels were taken from these pools (Starrett, 1971).

The presence (or absence) of certain molluscs in the lower reaches of the Illinois River gives an indication of the time required for at least partial dissipation of domestic and industrial pollutants from the Chicago-Joliet and Peoria-Pekin metropolitan areas (Starrett, 1971). Thisarea would provide an ideal study situation to monitor certain presumably adverse substances, and the survival of certain mussel species would then indicate those species which are sensitive to various agents.

Alterations in Mussel Populations

That agricultural, industrial, and domestic inputs into the Mississippi River and its tributaries have taken a great toll on the mussel fauna is obvious. Whereas total phosphate from these sources may not directly affect mussel populations, the contribution of total phosphates toward organic enrichment may be detrimental. However, the possible fragile state of mussel populations may not be readily apparent when one looks only at total numbers of species or of individuals. Consideration of the dominant species shows that Amblema plicata, the so-called "Three Ridge", is now the dominant species of the Upper Mississippi River (35.58 percent of

mussels collected--Table 6). This figure provides a striking contrast to the 8.03 percent figure in 1930-31 (van der Schalie and van der Schalie, 1950). Although pre-1964 data are lacking for the Illinois River, the dominance (62.40 percent) of Amblema plicata is significant (Table 6). This species is tolerant of adverse conditions, and has replaced species that were less common and more sensitive to changes in the river. Lampsilis teres, the dominant clam in the Mississippi River in 1930-31 at 14.03 percent, now ranks 25th, and accounts for but 0.21 percent of mussels collected by Fuller (1978). Though a popular clam in the button industry, Lampsilis teres had recovered by 1930-31 from apparent over-exploitation only to crash again as river conditions continued to deteriorate.

Other changes in relative abundance of mussel species are recognized (Table 6). It is likely that changes in habitat quality, as suggested for changes in Amblema plicata and Lampsilis teres populations, play an important role, but one should consider the possibility of natural cycles in populations as well as differences in sampling procedures as possible reasons for some variance. For example, Fuller (1978) writes of sampling so as to selectively collect juvenile Truncilla donaciformis. Likewise, the relative amount of sampling in the main channel versus backwater areas would significantly affect the relative position of a given species. For example, Lampsilis radiata siliquoidea fell from seventh to 23rd from 1930-31 to Fuller's (1978) survey, but this is probably due to a sampling artifact. Also, Cumberlandia monodonta, alway rare, may sometimes be overlooked due to its preference for a more rocky substrate, which may include submerged wing dams in the pooled portion of the Upper Mississippi River (Fuller, 1978).

Mussel populations may be adversely affected by anything that obstructs current. Emergent wing dams are probably noteworthy in this respect, because they set up currents which shift bars, erode stream banks, and increase suspended silt (Ellis et al., 1931). The increase in suspended silt limits light penetration and will limit the clams' phototactic responses. Suspended silt also causes the valves of clams to be closed to a greater extent than otherwise (Ellis, 1936).

The extent to which mussel populations are influenced by the distribution of fish hosts is an open question that has been discussed by Fuller (1978). There exist some examples where opportunities for glochidial attachment have been restricted. Noteworthy here is the restriction of the range of the skipjack herring (Alosa chrysochloris) by the construction of the power dam at Keokuk in 1913. The ebony-shell clam (Fusonaia ebena), once very important in the button industry, is now found only in small numbers above the Keokuk Dam. One problem in assessing the influence of fish host abundance on mussel distribution is that knowledge of fish hosts is incomplete for nearly all mussels. For example, when multiple hosts are known, it is not often known if there is a "preferred" or primary host. Clearly, glochidia-host relationships represent an area where additional study needs to be done.

Finally, one cannot overlook the effects of human endeavor on mussel fauna. The mussel industry on the Mississippi River has a long history

which continues in a limited extent to the present day, and the decline of some bivalve populations must be due in no small part to an historical rate of commercial harvest that exceeded replacement capabilities.

Endangered Species

Two endangered species, Proptera capax and Lampsilis higginsi, are known from the Upper Mississippi River. Lampsilis higginsi is also known from the St. Croix River.

Proptera capax probably ranged widely in the Mississippi River during the time of the Ellis survey (van der Schalie and van der Schalie, 1950). This species has recently been found subfossilized in Pool 24 (Perry, 1979); Fuller's 1978 survey failed to locate any living specimens. Proptera capax is not known to have any unique requirements in terms of habitat, and it is believed that its decline is due to a general decline in water quality (Fuller, 1978).

Lampsilis higginsi has always been rare in the Mississippi River. Recent surveys located this clam in several pools in the Upper Mississippi, and Fuller (1978) stated that "this mussel species is well suited to a recovery program because of the adequate volume of extant knowledge that would be necessary for such an undertaking, and because of the availability of breeding stock at Prairie du Chien."

While not an endangered species, the plight of Cumberlandia monodonta in the Upper Mississippi River deserves attention. This clam favors a habitat of rocky areas and it is usually found among boulders or in spaces beneath rocks. Such habitats are not common in the Mississippi River, partly because of natural conditions, and partly because of dredging operations which are carried out to facilitate commercial navigation. It is imperative that the Corps of Engineers and other interests concerned with navigation locate the habitats of Cumberlandia monodonta so as to spare this species from further decline in the Mississippi River. Post-1964 studies have located this mussel in five pools, the uppermost of which is Pool 15.

Fingernail Clams (Sphaeridae)

Fingernail clams are frequently abundant in benthic freshwater communities and are important in the aquatic food web. Important studies relating to habitat preference, vertical distribution, burrowing behavior, and seasonal variability have been done with study sites located in Pool 19 (see Gale, 1972; Gale, 1976; Gale, 1977; Rogers, 1976). Numerous surveys on the Mississippi River and its tributaries have focused on the availability of fingernail clams as an important food source. Sphaerids are eaten by numerous Mississippi River fishes, including gizzard shad, buffalo, sucker, redhorse, and drum; they are also important food items of diving ducks (e.g., Thompson, 1973). Fingernail clams occur both in the main channel and in side channel/backwater areas, but they seem to reach their greatest numbers in the latter habitats (Rada et al., 1980). Sphaerids are widely recognized as indicators of organic pollution and will react adversely when other macroinvertebrate faunas have been simplified (Hart and Fuller, 1974).

The importance of fingernail clams as a food source for diving ducks is shown by the tremendous numbers of diving ducks that use Pool 19 as a stopping place in their annual migrations. Pool 19 is the most heavily used of the pools by lesser scaup and is second only to Pool 8 in use by canvasbacks (Sparks et al., 1979). Heavy use of Pool 19 by the diving ducks is due, in part, to the large population of fingernail clams which are utilized as a food source (Wilds, 1973). Prior to 1955 the Illinois River was also an important stopping place for ducks using the flyway, but in 1955-56 water pollution seemed to have caused a population crash in the number of fingernail clams; this drastic decline coincided with a similar decline in the number of diving ducks using the Illinois River (Mills et al., 1966). It has been suggested (Rogers, 1976) that some of these ducks then began using Pool 19 as an alternative stopover.

The Asiatic Clam (Corbicula)

The alien Asiatic clam (Corbicula manilensis) was first discovered in North America in the Columbia River, Washington in 1938 (Thompson and Sparks, 1978). It has subsequently spread southward to Baja California and eastward to Florida (Eckblad, 1975). Corbicula apparently diffused northward in the Mississippi River from Louisiana and has been found as far upstream as Pool 9 (Eckblad, 1975; Rada et al., 1980); it has been taken north of Pool 9 in the lower St. Croix River (Fuller, 1978). Corbicula ranges into the upper Illinois River, where it has been taken as far upstream as the Marseilles Pool (Bellrose et al., 1977), and it has been collected from the lower Kaskaskia River (USAED, SL, 1975).

The initial occurrence of the Asiatic clam in the Illinois River was as recent as 1970-71 (Thompson and Sparks, 1977); the Asiatic clam also appears to have arrived recently in the Mississippi River above Cairo, Illinois (Eckblad, 1975). Corbicula is currently common in the reach of the Mississippi River from Pool 26 to Cairo, and is rare further north (Perry, 1979). One recent study, however, showed that locally abundant concentrations of the Asiatic clam should not be unexpected above Pool 26 at this time. A 1980 survey of a small area in Pool 19 examined 244 live mussel specimens and found that Corbicula was the most abundant of the fourteen species collected (Pagge and Schneider, 1980).

How far north abundant populations of Corbicula may range in the Mississippi River cannot be categorically delineated, because at least two possible limiting factors for the Mississippi, the temperature tolerance and preference of Corbicula, have yet to be determined (Thompson and Sparks, 1977). Regardless of eventual population sizes, however, the presence of Corbicula in the lower St. Croix River (Fuller, 1978) would appear to indicate that this clam cannot be excluded from any of nine-foot channel stream reaches of the Upper Mississippi River System by reference to low temperatures.

The invasion of the Asiatic clam may pose a threat to native bivalves. Gardner et al. (1976) found that a population rise of Corbicula in a five-mile stretch of the Altamaha River, Georgia was associated with precipitous declines of Unionids and Sphaerids. If that association is eventually found to be a cause-effect relationship that is relevant to the Upper Mississippi

River System, Corbicula will probably have some effect on the fish and waterfowl that feed on the native bivalves of the river system, though it is uncertain what those effects may be (Thompson and Sparks, 1978--see Fuller and Richardson, 1977, for a potential explanation for the negative correlation between Corbicula and mussels numbers found by Gardner et al., 1976). Corbicula is known to be a food source for dabbling and diving ducks and a number of fish species, but the comparative nutritive quality of Corbicula and native bivalves has not been fully researched (Thompson and Sparks, 1978).

Gastropods

Gastropod fauna of the Upper Mississippi River has received little attention. Other than some fairly extensive efforts in Pool 19 (see Gale, 1969), collecting seems to have been incidental at best, and the information that is summarized (Table 7) is provided only to point out gaps in the data.

It is indeed unfortunate that serious efforts have not been made in the study of Mississippi River gastropods. In view of the fact that snails may well serve as indicators of water quality (Hart and Fuller, 1974), gastropod data would be a valuable complement to the abundant and useful mussel information.

As in the case of the Mississippi River, there is a lack of information regarding gastropods of the Illinois River. Richardson (1928) observed changes in the Illinois River between Beardstown and the Peoria Narrows, wherein species, including "large snails," which he regarded as clean water forms during the period 1913-1915, had largely been eliminated by 1920-23. Paloumpis and Starrett (1960) provided 1950s gastropod information for three bottomland lakes in La Grange pool.

Oligochaetes

Extensive information regarding oligochaetes in the Mississippi River and its tributaries is limited to Pools 24, 25, 26 and the Alton Pool of the Illinois River. These areas were studied in depth by Colbert et al. (1975), who surveyed oligochaetes from the main channel, side channels, river border areas, and dike areas in the Mississippi and Illinois Rivers. Stations were sampled during high flow in July and during average flow conditions in September.

Tubificid oligochaetes comprised the greatest biomass (exclusive of clams) in the main channel (July) and in the dike areas (July), when the biomass was greater than that for insects (Colbert et al., 1975). Likewise, Rada et al. (1980) found oligochaetes to be the dominant organisms collected from the main channel of Pool 9. In other studies, oligochaetes were collected in a qualitative rather than in a quantitative way. A list of species found in the Mississippi and Illinois River is given in Table 8.

Oligochaetes derive the bulk of their nutritional requirements from the ingestion of micro-organisms in the organic matter of sediments and

soils. The quantity and quality of the organic material reaching the sediment may be important in determining the nature of the oligochaete community. This is bourne out in Pool 9, where the main channel stations with high organic content showed higher numbers of oligochaetes (Rada et al., 1980).

Oligochaetes are known to be a source of food for fish, but since a large part of the oligochaete population lies buried in the sediments, their importance in the diets of fish is probably not in proportion to their abundance.

Oligochaetes have received a good deal of attention as pollution indicators (Brinkhurst and Cook, 1974). Most of the pollution biology of oligochaetes is based on field studies,since physiological studies are lacking. It is, for example, recognized that certain conditions (e.g., heavy silting, high organic content of silt, and deoxygenation below organic effluents), will increase the total number of worms, but at the same time the number of species may be reduced. In such situations, the dominant forms may be thought of as indicators. For example, Tubifex tubifex and Limnodrilus hoffmeisteri dominated the fauna in a polluted segment of the River Derwent in England and thus might be regarded as indicators (Brinkhurst and Cook, 1974). However, it is important to recognize that these species have been around for a long time prior to the decline of environments. Thus, it is important, if the concept of an indicator organism is to be used, that particular attention be given to relative numbers, rather than the presence or absence of individuals. Such data are presently not available for the Mississippi River or its tributaries.

Insects

Insects are regarded as the most successful group of organisms in the Animal Kingdom, because they have become specialized so as to utilize almost every kind of habitat. In the aquatic environment, the number of species of insects respresents but a very small segment of the Class Insecta. Yet, in terms of biomass, the insects often represent a major component of the aquatic fauna.

The insect fauna of the Upper Mississippi and its tributaries is, for the most part, well studied. Noteworthy are the works of Kaminski (1973) on Pool 3, Fremling et al. (1979) and Fremling et al. (1973b) on Pool 6, Elstad (1977) on Pool 8, Rada et al. (1980) and Eckblad et al. (1977) on Pool 9, Hall (1980) on Pool 13, Carlson (1968) on Pool 19, Colbert et al. (1975) on Pools 24, 25, 26 Mississippi River and the lower Illinois River, and Ragland (1974) on the open river below St. Louis. Numerous other studies have involved sampling of insects as part of a general faunal survey.

Despite an abundant literature on Mississippi River insects, two generalizations regarding the direction of investigational effort are warranted. First, there is a deficiency in thorough taxonomic studies on insects. Second, quantitative data regarding insects are not available for a large part of the river. The above-cited studies represent attempts at quantitative assessments and/or taxonomic fine-tuning.

Rada et al. (1980) found the insect genera Cheumatopsyche, Hexagenia, Ablabesmyia, and Hydropsyche to be among the most abundant organisms (in terms of total numbers) in main channel sampling stations in Pool 9. These organisms were sampled in greatest numbers from the mid-channel. From side channel and associated backwater stations, the insect genera Hexagenia, Cheumatopsyche, Ablabesmyia, and Chironomus were the most abundant organisms.

Cheumatopsyche is a member of a large and dominant family of hydropsychid caddisflies living in running waters. They are net filter feeders, constructing silken nets anchored to a substrate that strain particulate material from the water. They occurred in numbers as great as $1504/m^2$ in Pool 9 (Rada et al., 1980).

Hexagenia sp. belongs to a group of burrowing mayflies that are found along the length of the Mississippi River. The nymphs show a preference for muddy substrates in which to build their burrows. They occurred in numbers as great as $2077/m^2$ in the Rada et al. (1980) study of Pool 9. Net-building caddisflies and Hexagenia have likely increased as a result of construction of the navigation system. Though both groups may, at times, reach nuisance levels, they constitute a tremendous fish-food supply.

Colbert et al. (1975) provide a list of insects collected in main channel, river border areas, dike areas, and side channels from Pools 24, 25 and 26, Mississippi River and lower Illinois River. The list totals about 50 species. In main channel stations, insects were the predominant benthic group found during each of two sampling periods (July and September); they comprised 55 and 98 percent, respectively, of the mean total density. Side channels, likewise, showed insects to be the predominant organisms in July, but in September they ranked behind oligochaetes in density.

The insects that appear prominently in collections from the Mississippi River are recognized as important items in the diet of fish. Hexagenia, for example, an important item in the diet of walleye (Fremling, 1980, personal communication), is produced in backwaters, while the accreted sediments in wing dams provide an important habitat for other organisms (e.g. Pentagenia) which play a major role in the food chain.

Roback (1974) provided a series of tolerance lists that show the genera of species that can tolerate extremes of some chemical parameters. Though the lists provide much useful information, the inter-relationships appear to be complex, for representatives of almost every group are tolerant of extremes in conditions. Thus, indicator organisms should be so designated only after careful study.

Other

Although leeches have not been the subject of extensive study, several investigators have provided lists of leech taxa from the Mississippi River. Cawley (1973), for example, listed seven species from Pool 10, and Gale (1975) listed eight species from Pool 19; all in all, a total of 12 species of Hirudinea have been reported from the Mississippi River.

Fremling (1980, personal communication) has noted that Hyallela sp. and Dugesia sp. are very abundant in wing dam rocks, where they usually outnumber insects.

ZOOPLANKTON

Zooplankters include several taxa of organisms that are of great importance in the food chain. For example, the significance of cladocerans in the aquatic food chain has long been recognized. Studies of gut contents of young fish show from 1 to 95 percent Cladocera by volume, and very few studies show less than 10 percent (Pennak, 1978). Immature insects (e.g., dipterans) are predators on cladocerans. Free-living copepods, likewise, constitute an essential link in the food chain, for they are on an intermediate trophic level between algae, bacteria, and protozoans on the one hand, and plankton predators (chiefly fish) on the other. Copepods, however, are not as important in the fish diet as are cladocerans (Pennak, 1978).

Despite the extreme importance of zooplankters, this assemblage of organisms is poorly studied in the Mississippi. Many inventories or surveys completely disregard zooplankers, while in other works, they appear to have been studied only cursorily. Some efforts, though, have resulted in the collection of useful data. Colbert et al. (1975) provided density data from main channel stations in Pools 24, 25, and 26, Mississippi River and lower Illinois River for July and September. Dieterman (1975) used types of zooplankters as a measure of pollution in Pools 3 and 4, and Eckblad (1973) and Midwest Aquatic Enterprises (1975) provided baseline data on the zooplankton of Pool 9 and in the open river area, respectively. Population and diversity data on rotifers were compiled by Williams (1966) for Pools 2, 12, 19 and the open lower Mississippi River, and the Illinois River.

Zooplankton studies, in order to be maximally useful, must involve consideration of the cyclic nature of populations and the uniqueness of the specific habitat. For the most part, cladocerans and copepods are almost nonexistent in waters carrying large amounts of sand and silt, but main-channel, side channel, and backwater populations all may be very high in silt-free habitats. Zooplankton populations are believed to influence phytoplankton densities by exerting grazing pressure during the bloom (Edmondson et al., 1962). In the Mississippi, this relationship probably exists within the navigation pools during periods of low to average flows.

Zooplankton densities are generally low throughout the Illinois River, but they increase in the lower reaches (Emge et al., 1974). WAPORA, Inc. (1972) reported that a peak in zooplankton populations occurs during late fall and early winter in the Illinois River, and that there is a lower abundance in the summer. In a comparison of the Alton pool of the Illinois River with Pools 24, 25 and 26 of the Mississippi, Colbert et al. (1975) found that copepod density was significantly greater in the Illinois River, and zooplankton evenness was greater in the Mississippi.

PHYTOPLANKTON

Phytoplankton is found in nearly all surface waters, where it collectively fixes solar energy which can in turn be used in other trophic levels in the aquatic food chain. In lotic systems, the dominant phytoplankters are the Chrysophytes, particularly diatoms (Hynes, 1970).

Investigations of phytoplankton in the study area were often made concomitantly with studies of zooplankton. Important studies are those of Claflin (1973a), who used the transect method to obtain baseline data on Pool 7, Claflin (1973b) on Pool 8, Eckblad (1973) on Pool 9, Colbert et al. (1975) on Pools 24, 25, and 26 of the Mississippi and Illinois River, and Midwest Aquatic Enterprises (1975) on the open reach of the Upper Mississippi River.

Colbert et al. (1975) collected 129 species of phytoplankton from main channel habitats during July and September sampling periods. Of the total species collected, 79 were diatoms of the division Chyrsophyta, 30 were in the Chlorophtya (green algae), and the remaining were distributed evenly between the Cyanophyta (blue-green) and the flagellated unicellular algae (Euglenophyta and Pyrrophyta). During July, Colbert et al. (1975) found the main channel habitat to be dominated by Chrysophyta, which comprised an average of 85 percent of the total phytoplankton collected at all main channel stations. The average total density of phytoplankton was 433/l. The total number of species collected from side channel habitats (129) was exactly the same as from the main channel during the same period, and the density was about 2800/l. From July to September, densities increased from 433/l to 48,511/l in the main channel, and from about 2800 (July) to about 6500 (September) in side channels.

From the representative studies cited above, it is apparent that phytoplankton is significantly more abundant during average river stages (September) than at higher (July) stages. The differences are more attributable to flow regimes than to nutrient limitations, since waterborne nutrients (nitrogen and phosphorous) were higher in July, when phytoplankton were at their lower densities. Colbert et al. (1975) suggest that plankton began to use these nutrients as the river dropped and more slack-water became present. As the phytoplankton became more abundant, dissolved oxygen also increased as a result of photosynthetic activity.

Side channels are very important habitats in the Upper Mississippi River and, especially during high flow periods, they provide a lower stream-velocity habitat with a relative abundance of phytoplankton. This abundance of phytoplankton provides a food source for phytoplankton feeders, such as zooplankton, insects, and planktiverous fish. During reduced river stages, the impounded river channel becomes more important as a habitat due to increased phytoplankton.

Phytoplankton concentrations below the Twin Cities waste treatment plant on the Mississippi River have been observed to be particularly high during low-flow summer conditions in the slack-water above Dam 2 (Hydroscience, 1979--the treatment plant is twenty-one river miles above Dam 2). Phytoplankton consume the nutrients released as the domestic sewage is decomposed. The process which accounts for these phytoplankton populations undoubtably makes algal blooms a regular occurrence below the Twin Cities, as would be the case in similar situations elsewhere. Some of the observed water quality effects of the phytoplankton growth were rises in the daily average levels and daily ranges of near-surface dissolved oxygen, pH, and the proportion of ammonia in an un-ionized form, which increases with increases in pH and temperature (Hydroscience, 1979).

Retrievals of phytoplankton analyses, made by the USGS at ten stations on the navigable segments of the Mississippi, Minnesota, Illinois, and Kaskaskia River, provide a source of information on phytoplankton occurrence in the study area. These raw USGS data were not assessed in this study.

FISHES

The Upper Mississippi River, with its environment altered by the construction of 29 navigation dams, offers unique environments for fish habitation. A generally more stable and less turbid environment exists presently as compared to the former free-flowing river. Impoundment of the river expanded surface waters and greatly increased aquatic productivity, but it also created the beginning of a process that is filling the artificial pools with sediments. Habitats that were formerly ecologically rich are being lost through sedimentation. Thus, numerous efforts have been made to monitor fish populations throughout the Upper Mississippi River and its tributaries. These efforts have utilized permanent sampling stations, test and exploratory fishing, creel surveys, aerial surveys, and tagging and marking programs. Further, commercial fishermen operating on the Upper Mississippi are required to report their catch to their respective states, and these statistics are compiled each year.

A total of 139 species of fish has been collected and identified from waters of the Upper Mississippi River since record keeping began in the late 19th century. The data on the occurrence and status of Mississippi River fish have been organized into a distributional atlas by Smith et al. (1971). A classification scheme regarding the occurrence and relative distribution of fish in the Upper Mississippi was developed by Rasmussen (1979) and is given in Table 9. Rasmussen (1979) has provided a concise assessment of the status of fish species of Upper Mississippi River, and his account is given here.

> There are only four species which are classified as abundant throughout the river. These are gizzard shad (Dorosoma cepedianum), and carp (Cyprinus carpio), emerald shiner (Notropis antherinoides), and a bluegill (Lepomis macrochirus). The gizzard shad and emerald shiner are important forage species; the carp is the most important commercial species in the river; and the bluegill is an important gamefish. Although not classified as abundant throughout the river, the river shiner (Notropis blennius) and bullhead minnow (Pimephales vigilax) are plentiful in most areas and provide significant contributions to the river's forage base.
>
> Thirteen species are common to the entire river, but generally support smaller populations than those classified as abundant. However, during spawning migrations or in certain specific locations such as below the navigation dams, near wing dikes and near submerged brush, large concentrations

of species such as white bass (Morone chrysops), white crappie (Pomoxis annularis), black crappie (Pomoxis nigromaculatus), sauger (Stizostedion canadense), and freshwater drum (Aplodinotus grunniens) may be encountered. Shortnoe gar (Lepisosteus plastostomus) and bowfin (Amia calva) are commonly collected and are considered important predators which compete for food with the more popular gamefish such as bass and crappie. The silver chub (Hybopsis storeriana) and river shiner are considered forage species; while the bigmouth buffalo (Ictiobus cyprinellus), channel catefish (Ictalurus punctatus, flathead catfish (Pylodictis olivaris), and freshwater drum are important components of the commercial harvest. The white bass, largemouth bass (Micropterus salmoides), white crappie, black crappie, sauger, and channel catfish are considered important gamefish.

Thirty species are considered common or abundant in certain portions of the river and occasional, uncommon, rare or a stray from a tributary or even nonexistant in other river reaches. This phenomenon can probably be attributed to environmental preferences which characterize the natural range of the species. Species such as the northern pike (Esox lucius), mooneye (Hiodon tergisus), white sucker (Catostomus commersoni), trout-perch (Percopsis omiscomaycus), rock bass (Ambloplites rupestris), yellow perch (Perca flavescens), logperch (Percina caprodes), and walleye (Stizostedion vitreum) appear to prefer the relative clarity, coolness, and quiteness of the upper, pooled portions of the river. On the other hand, species such as the goldeye (Hiodon alosoides), flathead chub (Hybopsis gracilis), and red shiner (Notropis lutrensis) seem to thrive in the lower, more turbid reaches of the open river.

Species worthy of mention which occur on an occasional basis in the river include the chestnut lamprey (Ichthyomyzon castaneus) and the silver lamprey (Ichthyomyzon unicuspis). As with many lampreys, both Mississippi River species are parasitic during a portion of the adult life, attaching themselves to the bodies of other fishes for several days at a time feeding on the blood of the host fish. The American eel (Anguilla rostrata), considered a prized delicacy by some fishermen, is unusual in that it migrates to the Sargasso Sea area of the Atlantic Ocean for spawning purposes. The yellow bass (Morone mississippiensis) has in recent years begun to decline significantly in numbers in the upper portions of the river. The small mouth bass (Micropterus dolomieui), although never present in large numbers in the river and very uncommon in southern river reaches, always creates a special excitement among anglers since it is held in high esteem by most sport fishermen.

The most controversial species in the "occasional" category is the grass carp (Ctenopharyngodon idella). Only a few

years ago this species was considered a straggler in the river. Grass carp were introduced state-wide in Arkansas in the early 1970's and more recently on an experimental basis in Iowa. The species is beginning to appear in the catches of commercial fishermen in both the Mississippi and Missouri rivers. Nearly 6,500 lbs. were included in reported catches of commercial fishermen from pools 20, 22, 24, 25, 26, and B-26 in 1976. Total reported catch of grass carp dropped to 3,651 lbs. in 1977, but included 15 and 100 lbs. from pools 17 and 15, respectively. Thus the known occurrence of the species has been extended into two more pools. It is possible that the grass carp might eventually establish itself as a common component of the Mississippi River fishery in most river reaches. Depending on point of view, this could spell success or disaster.

Species classified as uncommon (U) exist in small numbers in the Mississippi River and do not necessarily appear to be diminishing in numbers as a result of man's activities. Therefore, they will not be considered in this discussion.

Those species listed as rare in all or portions of the river are in many cases being extirpated from their natural range and deserve special consideration in all aspects of river management. The same is true for those species which were previously collected from the river, but have not been included in UMRCC samples during the last ten years (H). The lake sturgeon (Acipenser fulvescens), for example, was once an important component of the Mississippi River commercial fishery. Its numbers have declined drastically in this century probably due to overfishing, water pollution and the construction of dams which have blocked its movements and destroyed habitat. In the summer of 1976, however, several specimens of lake sturgeon (18-24 in. in length) were reported taken by fishermen from a fishing float below Lock and Dam 4. This pheonomenon had not occurred before and has not been reported since. The cause of the occurrence remains a mystery.

Twenty-seven species are recorded for the river as stragglers from tributary waters. Fourteen additional species are listed as stragglers in certain portions of the river, while in other portions they are given a different status. Only one straggler species is so unusual that it is worthy of note. This is the bull shark (Carcharhinus leucas). One specimen of this estuarine species was recorded in Pool 26 in 1937. The bull shark is the only shark known to be able to deal with the osmotic demands of either fresh or salt water for extended periods. The Mississippi River meets the requirements of "exploring" bull sharks at least during the summer and early fall when water temperatures rise above 23° C. However, the occurrence at Alton is about as far upstream from the Gulf of Mexico as one could reasonably expect to encounter a bull shark, even if the navigation dams were not present. Thomerson goes on to state that

bull shark can reasonably be looked for occasionally at points farther down the river.

There are presently no Mississippi River fish species included on the federal list of Threatened and Endangered Species. Each of the five UMRCC states, however, have listed species which are considered threatened within their jurisdictional boundaries. This can be attributed to the fact that a given state may lie on the fringes of the natural geographic range of a species. Thus a given state may support extremely limited numbers of the species while the species as a whole may be relatively plentiful on a national or regional basis.

Wisconsin lists the paddlefish (Polyodon spathula) as "a species that may or may not be holding its own at the present time", while the species is included in both the commercial and sport catch in the states of Iowa, Missouri and Illinois. Other Mississippi River species similarly listed in Wisconsin include the pallid shiner (Notropis amnis), weed shiner (Notropis texanus), striped shiner (Notropis chrysocephalus), blue sucker (Cycleptus elongatus), American eel and longear sunfish (Lepomis megalotis). Wisconsin lists the Ozark minnow (Dionda nubila) and pugnose shiner (Notropis anogenus) as endangered.

The state of Missouri lists the alligator gar (Lepisosteus spatula), Alabama shad (Alosa alabamae), sturgeon chub (Hybopsis gelida), sicklefin chub (Hybopsis meeki), brown bullhead (Ictalurus nebulosus), burbot (Lota lota), and pumpkinseed (Lepomis gibbosus) as rare; the lake sturgeon, pallid sturgeon (Scaphirhynchus albus), and pugnose minnow (Notropis emiliae) as endangered; and the pallid shiner as possibly extirpated.

The state of Illinois lists the lake sturgeon, alligator gar, and pugnose shiner as threatened.

The state of Minnesota lists six categories of plants and animals which merit varying degrees of special consideration and management. Mississippi River fishes included on this listing are the lake sturgeon, paddlefish, blue sucker, pugnose shiner, blue catfish (Ictalurus furcatus), and skipjack herring (Alosa chrysochloris). The lake sturgeon and paddlefish are listed as species that are:

> "uncommon or local in Minnesota, which are not presently endangered or threatened, but which could become threatened. Conversely, they could increase under favorable circumstances."

The blue sucker and pugnose shiner are listed as species that:

> "merit special consideration in Minnesota, and in some places and at some times, merit special management be-

cause of unusual or unique values, special public interest, or vulnerability of habitat."

These two species are not presently considered endangered or threatened in Minnesota, but should be watched. The blue catfish and skipjack herring are listed as:

"Species that once lived in Minnesota, but which were early extirpated, or nearly so. Because of habitat loss or alteration associated with increase in human population and changes in land and water use, there appears to be little possibility of re-establishing viable, sizable wild populations."

Iowa lists the lake sturgeon, pallid sturgeon, sicklefin chub, silverband shiner (Notropis shumardi), pearl dace (Semotilus margarita), starhead topminnow (Fundulus notti), longear sunfish, and orangethroat darter (Etheostoma spectabile) as endangered; and the chestnut lamprey, skipjack herring, grass pickerel (Esox americanas vermiculatus), gravel chub (Hybopsis x-punctata), pugnose shiner, weed shiner, western sand darter (Ammocrypta clara), mud darter (Etheostoma aspirgene), and bluntnose darter (Etheostoma chlorosomum) as threatened. The Alabama shad and the sturgeon chub are considered possibly extirpated in Iowa, while the status of the pugnose minnow (Notropis emiliae) and the crystal darter (Ammocrypta asprella) are undetermined in that state.

Fish surveys in the Illinois River were made during the period 1931-1937 by Dr. David H. Thompson and his assistant, Dr. Donald F. Hansen. Sampling, using hoop nets, was done in stations from Marseilles, Illinois to near Meredosia, just downstream from the La Grange dam. Because of the absence of fish in the upper segment of the Illinois, few stations in the upper reaches were included in the survey. In 1942, these same workers conducted a second comprehensive fish survey and, during the period from 1957 to 1971, a number of netting and electro-fishing studies were conducted by Dr. William Starrett. Finally, data were collected by Dr. R. Sparks and Mr. Carl Thompson during the period from 1973 to 1976. The results of all of the above studies are given in Tables 10 and 11.

More than 45 species of fish were taken from the Illinois River in the three hoop-netting surveys conducted between 1931 and 1967. In the pre-1939 studies the black crappie was the predominant fish recorded. Bellrose et al. (1977) have noted that the high prevalence of the black crappie is due in part to the fact that much sampling was done in Lake Senachwine. If the fishing effort in Lake Senachwine had been the same in the pre-1939 surveys as in the later surveys, black crappies would have accounted for only about 30 percent of the catch in the pre-1939 surveys. Similar adjustments for some of the other species commonly taken in pre-1939 surveys result in the following percentages: catfishes, 14 percent; bluegills and white crappies, 15 percent each; and gizzard shad and carp, 9 percent each.

The general trends in catch composition show that the percentage contributions of the sport fishes, such as crappie, have declined since 1942, while the percentages contributed by rough fishes have increased. Catfishes, a mixed group of edible fishes, showed a general increase in the percentage composition of the catch after 1942, but the 1957-1967 catfish catch was composed mostly of the more tolerant black bullhead, whereas the more desirable blue and channel catfishes had been nearly eliminated from the catch (Bellrose et al., 1977).

The data on fish that have been extirpated from the Illinois River lists 19 species of minnows and other small-size fish that are normally not caught in hoop nets. Exceptions are the creek chubsucker, spotted sucker, and cisco, which is an immigrant from Lake Michigan. Thirteen other species whose numbers and range have been severely limited in the last 79 years are: shovelnose sturgeon, silvery minnow, river shiner, brown bullhead, pirate perch, burbot, brook silverside, yellow bass, pumpkinseed, longear sunfish, spotted sunfish, river darter, and walleye.

Of the species that were lost or reduced, the Ozark minnow has probably been most affected by the nine-foot channel project, because this fish requires a coarse bottom material and a strong current (Bellrose et al., 1977). Impoundment has enhanced sedimentation and reduced the current to an impercepitable flow at low water levels (Starrett, 1972). Some other species (e.g., the pugnose shiner, blackchin shiner, blacknose shiner, and weed shiner) have probably disappeared as a result of increased sedimentation. A number of other species which are rarely found in the river today were caught in sizable numbers in 1942. Of these, the yellow perch, yellow bass, pumpkinseed, blue sucker, brown bullhead, and sauger have virtually disappeared from the river above La Grange, primarily due to the reduction of aquatic vegetation, covering of the sand bottom by sedimentation, or high turbidity—all related problems to which the navigation dams and boat traffic have contributed (Bellrose et al., 1977).

Fisheries biologists have attempted to evaluate fish condition in various ways. One type of effort was that of Carl Thompson of the Illinois Natural History Survey. A condition factor for carp was developed, and an increase in carp plumpness was shown to occur with an increase in bottom fauna biomass. Thus, any influence on the bottom fauna would cause changes at higher levels of the food chain, such as a change in the condition factor of bottom-feeding fish like carp. The die-off of fingernail clams (see section on Benthic Macroinvertebrates) in the Peoria and the La Grange pools in the mid-1950s was probably the major cause of the decline in the condition factor of carp between 1942 and 1970 (Bellrose et al., 1977).

A condition, known as knothead, occurs in carp and has been found to be associated with a deficiency of Vitamin D. Further, this rickets-type disease may likely be due to the loss of green algae and macrophytic vegetation from the river as a result of pollution, so knothead may serve as a pollution indicator. Results of various recent studies show the incidence of knothead to range from 88.5 percent in the upstream areas to 9 percent below the La Grange dam. This condition has not improved since 1942 and has worsened in one pool (Peoria).

Due principally to loss of aquatic vegetation, a delince in fish populations of the lower Illinois River since 1950 has virtually wiped out commercial fishing. In fact, conditions of the Illinois River have declined so much that the remaining fish markets along the river do not even handle Illinois River fish.

VERTEBRATES OTHER THAN FISHES

A discussion of recent faunal changes in the Upper Mississippi, Minnesota, and St. Croix Rivers, and Illinois Waterway has been presented in a recent (1977) report by a group of U.S. Army Engineer Districts. In this report, vertebrate fauna (other than fishes) are discussed according to habitat: forest, brush, meadow, sand and mud flats, agricultural land, and marsh (refers to aquatic macrophytes in general).

Appended to this paper is a composite list of the national and/or state threatened and endangered vertebrate species (other than fish) that are applicable to the GREAT I and II study areas (GREAT I, FWWG, 1979; GREAT II, FWWG, 1980--see Appendix C). Listings, with discussions, of amphibians, reptiles, birds and mammals of the Upper Mississippi River System have been compiled for Pool 1 to 10 (GREAT I, FWWG, 1979), Pool 11 to 22 (GREAT II, FWWG, 1980), Pool 24, 25 and 26 of the Mississippi and lower Illinois River (USAED, SL, 1975a), Middle Mississippi River (Terpening et al., 1974;USAED,SL,1976),and the Illinois Waterway above Alton pool (USAED, NCD, 1975). Terpening et al. (1974) is a good discussion of the ecological relationships on the floodplain of the Middle Mississippi River.

I. Forest (Bottomlands). The main game fauna of the forest are white-tailed deer and tree squirrels. Because of conversion of land from private to public ownership, and because of improved management, deer populations have increased. Squirrel (gray and fox) populations have decreased due to the loss of mast-producing trees (USAED, 1977; Collins, 1977).

Wood ducks, which usually breed in the forested bottomlands and woodland streams, are abundant and show a major increase over populations at the turn of the century, when wood ducks were near extirpation (Bellrose, 1976). Populations recovered because the wood duck has been protected by hunting controls, has adapted to some human disturbance, has the protection of refuges, and has adapted to different foods (e.g., aquatic vegetation, corn). In addition, the racoon (a main predator) is at a lower population level (USAED, 1977). The bottomlands of the Illinois River, and of the Mississippi River from just below the Twin Cities to the Gulf Coast are prime breeding habitat for wood ducks; the reach of the Mississippi from St. Louis to Cairo is part of the secondary wintering range of the wood duck (Bellrose, 1976).

The bald eagle uses river bottom forests for roosting and feeding (USAED, 1977). It has declined, probably due to insecticides, nesting encroachment, and other human disturbances. Concentrations of bald eagles occur from late fall to spring, during which time they feed in open water below the navigation dams (tail waters) and at heated-effluent discharge sites (for example, electrical generating plants). Surveillance of bald eagle populations in the Upper Mississippi River System is maintained by

the National Wildlife Federation, U.S. Fish and Wildlife Service (Mark Twain Wildlife Refuge, and Upper Mississippi River Wildlife and Fish Refuge), and the Illinois Natural History Survey.

II. Brush. Areas of underbrush and young trees in the Upper Mississippi River are, overall, less prevelant now than in pre-impoundment times (USAED, 1977). The indicators for the brush-type habitat are fox, raccoon, woodcock and opossum. Also, this type of habitat is of value in wood duck breeding, especially if the brush land is frequently flooded (USAED, 1977). Because of its present small acreage, this habitat type probably does not have a significant impact on the indicator species, which are multiple cover type users (USAED, 1977).

III. Meadow. The species typical of the meadow habitat are upland game birds, certain shore birds, skunk, fox, badger, and nesting waterfowl. After impoundment, this habitat was sharply reduced with adverse effects for species such as quail and shorebirds. On the other hand, the decrease of grazing and hay-cutting on the meadows that remained has rendered this habitat more suitable for nesting waterfowl and shorebirds.

IV. Sand and Mud Flats. The indicator species of this habitat are shorebirds, waterfowl, and reptiles. For shorebirds and waterfowl, this habitat serves primarily as a resting area. Many of the common dabbling ducks are heavy consumers of the moist-soil plants that volunteer on the mud flats exposed during the growing season (Bellrose et al., 1979). For turtles, the area is utilized for nesting. A net reduction in sandbars has reduced the quantity of nesting habitat for turtles (Cawley, 1973). Sandy dredge spoil deposits offer newly created habitat for turtles.

Shorebirds (e.g., greater and lesser yellow legs, least sandpiper, dowitcher, and turnstones) are generally found on the sand and mud flats during migration (USAED, 1977). Woodcocks and Wilson's snipe prefer mud flats for feeding and use brush or swamps for cover. Declines in these species are due to hunting and disturbance of nesting land by agriculture (USAED, 1977).

V. Agricultural Land. Typical species for this habitat would be racoon, groundhog, rabbit, quail and waterfowl. Cleaner farming and larger fields have reduced the habitat and available food for these species, so habitat quality and quantity have decreased for the wildlife community (Collins, 1977). Certain species of waterfowl, however, are major exploiters of cultivated grains (e.g. corn, wheat) in the Upper Mississippi River drainage and elsewhere. Principal ducks among these are the mallard, the most abundant waterfowl species in North America, and the pintail, the second or third most populous in North America (Bellrose, 1976). The increasing consumption of cultivated grains, from both farms and refuges, has been a prime reason for the continental population rise in the last two decades of the Canada goose (mainly interior race in study area, with a smaller number of the giant race -- Bellrose, 1976).

Waterfowl reliance on the cultivated grains of farms is not the most propitious means to maintain populations. Land use conflicts can arise between farmers and waterfowl supporters over the setting aside of addi-

tional wetlands for waterfowl (Bellrose, 1976), and future increases in the efficiency of harvesting equipment will cause a drop in waste grain available for waterfowl (Bellrose et al., 1979). Bellrose et al. (1979) have described an on-going water management technique in the Illinois River Valley for enhancing the productivity of natural waterfowl plant foods.

VI. Marsh. Marshes are naturally fertile ecosystems which act as a vital ecological transition area between open water and moist shoreline (Odum, 1963). Marshes support mink, otter, muskrat, soft-shelled turtle and water snakes. Additionally they provide cover and feeding areas for waterfowl, and are spawning areas for fish.

The Mississippi Flyway is of continental importance. Twenty-eight species of waterfowl (ducks, geese and swans) use the Upper Mississippi River Wildlife and Fish Refuge (UMRWFR) -- (GREAT I, FWWG, 1979). The most common ducks of the UMRWFR, or pooled reach below, are mallard, pintail, blue-winged teal, wigeon, ring-necked duck, and scaups (Table 12). A great increase in overall duck utilization of the UMRWFR, and a shift from a preponderance of diving to dabbling ducks resulted from an increase in aquatic plant productivity following impoundment (Green, 1970). Dabbling ducks, as a group, feed more on seeds and leafy portions of emergent aquatic and moist soil plants than diving ducks, which have a diet more concentrated in animal sources (insects, mollusks) and submersed aquatic plants (Anderson, 1959).

The whistling swan is a common species in the upper pooled river between La Crosse and the Twin Cities,but not further south. Its migration corridor between its tundra breeding grounds in Alaska and northwestern Canada, and its wintering grounds near Chesapeake Bay is concentrated between those two cities (Bellrose, 1976). Of the geese, the Canada and lesser snow goose are the common species of the Upper Mississippi River (Table 12). The southernmost part of the Upper Mississippi River is an important wintering area for the Canada goose (Bellrose, 1976).

The abundant waterfowl of the Upper Mississippi River are those with relatively large continental populations that have important wintering or breeding grounds about the river valley, or that utilize the valley as a feeding and resting site during migration between important wintering and breeding grounds (for details on each species, see Bellrose, 1976). It is not surprising, then, that largely the same set of waterfowl species that frequents the Illinois River Valley (Bellrose et al., 1977) also frequents the Mississippi River Valley (Table 12). Outstanding exceptions to the waterfowl similarity between the two rivers are found for three species of diving ducks, whose populations experienced precipitous declines in the mid 1950s in the Illinois River Valley and have remained low since that time. The species are lesser scaup, ring-necked duck and canvasback (Mills et al., 1966). These population declines were associated with the disappearance of the fingernail clam (Mills et al., 1966). All three of these species remain heavy users of the Mississippi River (Table 12).

Ringnecks utilize the Mississippi Flyway as a prime corridor between their principal breeding grounds in the Prairie Provinces of Canada and their principal wintering grounds along the Gulf Coast (Bellrose, 1976). Lesser scaup also employ the Mississippi Flyway as an important corridor, and Keokuk Pool (Pool 19) is one of its most important migration areas in the contiguous United States (Bellrose, 1976). Lesser scaup feed heavily on animal foods, especially fingernail clams, in the Keokuk Pool (Thompson, 1973). Whereas lesser scaup and ringnecks have their major migration corridors oriented north/south, canvasbacks migrate primarily east/west between their prairie breeding grounds and principal wintering grounds at or near Chesapeake Bay (Bellrose, 1976). The eastward migration corridor bifurcates in western Minnesota, with one prong traveling to the upper pooled river (especially Lake Onalaska in Pool 7 and Wisconsin Island in Pool 8) and the other prong traveling to the lower pooled river (especially Keokuk Pool). Much of the population of cans in the two prongs reconverges at wintering grounds along the Atlantic Coast. The route from Keokuk Pool to the Coast traverses the Illinois River Valley. On the Keokuk Pool, canvasbacks have fed principally on animal sources in recent times (Thompson, 1973), whereas earlier (1938 to 1940) on the Illinois River Valley, canvasbacks had a diet comprised of a more even balance between animal and plant sources, with the latter source being dominant (Anderson, 1959). Submersed aquatic plants were the most important of the plant foods (Anderson, 1959).

Wading birds, such as great blue herons, the great egret, and the black-crowned night heron, are communal nesters in marshes (black-crowned night heron) and forests (great blue heron and great egret). Various population assessments indicate that great blue herons and great egrets have declined since reaching a population peak in the 1960s (USAED, 1977). The causes for the decline are not understood, but may relate to degradation of nesting and feeding habitat. Polychlorinated biphenyls (PCB's) are postulated to affect the reproductive cycle of great blue herons (USAED, 1977 — see Hora (1977) for some data on PCB's residues in great blue herons of the Mississippi River).

Thompson and Landin (1978) investigated the nesting distribution of great blue herons and great egrets in the portion of the Upper Mississippi River from Pool 2 to 26. As noted above, these species have experienced general population declines, and the declines appear to have been more severe in the lower pooled river than in the upper pooled river. The distribution of nesting populations of these species is relatively large, in general, from Dam 1 to Dam 13. Nesting populations experience a discrete drop from Pool 13 to 14 and remain low downstream to Pool 26. Within pools, great blue herons and great egrets have an affinity for nesting in the forests of the upper reaches, near the river shallows in which they feed. These two species also have a nesting preference for tributary junctions, where they nest in the forests of the tributary delta. It may be that the tributary junction and upper pool nesting preferences of the great blue heron and great egret are a reflection of their preference for river-adjacent forest habitats that most closely approximate those of pre-impoundment times (Thompson and Landin, 1978).

AQUATIC AND TERRESTRIAL VEGETATION

The aquatic and terrestrial vegetation of the river environs represent an integral component of the habitat of fish and wildlife. Birds and mammals utilize the vegetation communities for food, nesting, and protection. Fish are afforded food, shelter, and a setting for the deposition of eggs by aquatic vegetation (Fassett, 1957). Aquatic vegetation provides habitat for small animals and algae that are used, directly or indirectly, as food for fish (Fassett, 1957). The chemical and physical character of the water are moderated by aquatic plants (e.g., Smart, 1977; Jackson and Starrett, 1959). Water quality is also affected by the influence of terrestrial vegetation cover on quality and quantity of overland runoff. Changes in the aquatic and terrestrial vegetation communities have had a significant effect on the water-associated species that exploit the river environs (Bellrose et al., 1977; Bellrose et al., 1979; Green, 1970; Sparks et al., 1979; USAED, 1977).

The emphasis of the following discussion is on wetland vegetation. Phytoplankton has been discussed in a previous section. The reasons why there are no subheadings for the Minnesota River, St. Croix River, and Kaskaskia River are described under "Information Sources".

Information Sources

Remote-sensing studies provide a recent (1975) vegetation assessment of the Upper Mississippi River from Pool 3 to the confluence of the Ohio River (Minor et al., 1977; Hagen et al., 1977). In these studies, vegetation was interpreted from air photos that were taken during the normal low water conditions of the summer. Plant categories were identified with the dominant genus or species, or with the dominant associations of genera or species, or with the human use of the plant, for example, agricultural crops (see Appendix A). The specificity of aquatic and marsh vegetation categories is greater in the reach from Pool 3 to 10 (Minor et al., 1977) than in the reach from Pool 11 to the Ohio River (Hagen et al., 1977).

Remote sensing was also used to describe the 1973 vegetation distribution of Pool 1 and 2, and of the lower Minnesota and lower St. Croix River (Olson and Meyer, 1976a; or Olson and Meyer, 1976b). In this study, plants were identified with general categories (e.g., meadow, forest). The general vegetation category that includes true aquatics has no taxonomic breakdown, and all species are subsumed under the label of "marsh". These general marsh figures were presented previously (Table 1) and are not represented here.

Submergent aquatic vegetation was not capable of being assessed in the 1973 remote-sensing study of Pool 1 and 2, and of the lower Minnesota and lower St. Croix River, because the type of photographic film used in the assessment did not penetrate the water surface (Olson and Meyer, 1976b). Water-penetrating film was utilized in the studies that cover the reach from Pool 3 to the Ohio River, but the relatively high turbidity of the Mississippi prevented a reliable assessment of the submersed aquatic beds (GREAT I, FWWG, 1979). In other words, there is no firm guarantee that

the submergent aquatics that were found were due to anomalously low turbidity levels at the times the photos were taken.

Submersed aquatic vegetation was commonly found in association with carpets of duckweeds (Lemnaceae) and floating-leaved species, both of which prevented "seeing" the full extent of the submergent aquatic beds on the air photos. Partial compensation for this was accomplished through field checking the vegetational associations between submersed and covering plant types, and including plant associations as reporting categories.

The lack of full and reliable submergent data is a significant information gap in schemes that attempt to employ this data set for a broad evaluation of habitat suitability for fish and wildlife (GREAT I, FWWG, 1979; ERSI, no date). It also represents an uncertain basis from which to judge the effect of environmental alterations on aquatic vegetation. Submersed aquatics are sensitive to a wide spectrum of environmental disruptions (see Davis and Brinson, 1980, for a general discussion). One such disruption is increased turbidity, which, because of its intimate association with siltation, is of general concern throughout the Upper Mississippi River System. Although the submersed plant data have shortcomings, the data are discussed, and the discussion is interpreted as a presentation of information gained from the application of this particular assessment technique.

Data for the Illinois River are taken principally from Bellrose et al. (1977) and Bellrose et al. (1979). Both studies evaluated the changing wetland vegetation resources of the Illinois River, and both have drawn on the detailed historical vegetative monitoring that has been conducted on the Illinois River.

For the lower Kaskaskia River, this study did not locate works that presented wetland vegetation sampling records which were applicable after the lower river was modified for commercial navigation.

Primary information sources are supplemented by works that illustrate the abundance and diversity of aquatic and marsh vegetation within particular river reaches. Such works are particularly important for the Mississippi, because the primary information source (remote sensing) sacrifices detail for areal coverage. However, the literature search conducted for this study found few detailed studies of the Mississippi reaches. Most of the studies that were found dealt with vegetation typing only, and not with the relative biomass or relative frequency of the plant species. Considering collectively all of the studies found in the literature search, the quantity of recent sampling for wetland plants is relatively high for Pool 7 and 8, with moderate to light sampling for the remaining pools in the reach from Pool 3 to 10. Thirty-one studies that sampled for vegetation were identified for the reach from Pool 3 to 10 (see Supplement A). Most of these studies, however, identified few species, mainly because vegetation sampling was not a primary focus. Other than the studies for the reach from Pool 3 to 10, a recent work on Pool 19 (Schuyler, 1980) and on Pools 24, 25, and 26 of the Mississippi and lower Illinois River (Klein et al., 1975) were found. For all other pools or reaches, including the lower Minnesota, lower

St. Croix, and lower Kaskaskia, sampling was found to be either nonexistent or virtually nonexistant. In addition, quantitative historical records on the abundance and diversity of aquatic and marsh plants were not located, except for the quite general kind of records that were utilized in the section on pre-impoundment or early post-impoundment distributions of marsh vegetation. This comment on historical records applies throughout the Upper Mississippi River and includes the lower Minnesota, lower St. Croix, and lower Kaskaskia River.

Mississippi River

The reach of the river above Dam 10 has large tracts of aquatic vegetation. In the aggregate, the emergent aquatics (marsh) dominate, with the duck potato (Sagittaria latifolia) and bulrushes (Scripus spp.) being the species identified with the dominant categories (Table 13). These same species are also identified with category "22". The relatively large presence of submergent aquatic plants (category 19, and portions of 17 and 10) is significant, considering that these categories are being compared with a reach of the river with extensive floating-leaved aquatic and marsh cover (Table 1). Pool 7 to 9 have major beds of the category Vallisneria-Potamogeton-Heteranthera. The floating-leaved lilies (Nymphaea spp.) are the most commonly identified species in association with submergent aquatics. The concentration of Nymphaea sp. in Pool 6 is a singular anomally for this reach of the river.

Sefton (1976) has conducted a detailed vegetative inventory of Pool 8. Forty-one study areas were chosen to provide an effective sample of the range of aquatic macrophyte habitats that occur in Pool 8. Most of the study areas were sampled twice, once in early summer and once in late summer of 1975. The results from all sampling sites and areas are combined in Table 14. The flora of Pool 8 is considered typical of the upper river (Sefton, 1976).

In terms of frequency (probability of finding a species at vegetated collection sites within the study areas), submersed aquatic species are dominant, with the pondweeds, (Potamogeton spp.), coontail (Ceratophyllum demersum), wild celery (Vallisneria americana), and water weed (Elodea (Anacharis) canadensis) comprising most of the frequency of the submersed aquatics (Sefton, 1976). Emersed aquatics, however, dominate the relative biomass (dried weight of total plant). Duck potato accounts for just under one-half of the aggregate biomass. The quantitative data collected by Sefton (1976) represent the best single set of baseline information on the composition and habitats (see original work) of aquatic macrophytes for any Mississippi River pool found during this study.

Sohmer (1975) sampled aquatic vegetation along two traverses, one in Pool 7 and one in Pool 8, in late summer 1973 (Table 14). A comparison between the sampling results of Sohmer (1975) and Sefton (1976) reveals that both found largely the same set of dominant submergent and floating-leaved species, but that species contributions to total biomass contain some large differences (Table 14). Sefton (1976) has attributed much of the biomass differences to sampling variability and to the types of habitats sampled. Vallisneria americana, for example, was the largest contributor

to biomass of the submergent and floating-leaved species found by Sefton (1976),but the species was ranked sixth by Sohmer (1975)--(Table 14). Vallisneria americana is common in lower Pool 8, and rare in the midsection of Pool 8 (Sefton, 1976). Sohmer (1975) sampled only the middle sections of Pool 7 and 8, while Sefton (1975) sampled both the middle and lower section of Pool 8.

The aquatic flora of Pool 8 was rather thoroughly sampled in 1975 and 1976 by three studies (Sefton, 1976; Swanson, 1976; and Ziegler and Sohmer, 1977). These three studies, in combination, provide an indication of the diversity of aquatic and marsh vegetation in Pool 8. Fifty-five aquatic plants were identified to species, and thirteen of these species were submersed aquatic plants.

The remote-sensing study of reach above Dam 10 used categories of aquatic and marsh vegetation that are difficult to match consistently with the categories utilized in the remote-sensing study that covered the reach below Dam 10. In the reach from Pool 11 to Cairo, the dominant categories, in the aggregate, are Sagittaria spp., Nelumbo lutea and the category "submergent aquatics" (Table 15). The abundance of the category Sagittaria spp. appears to drop off in the lower pooled reach, while the category Polygonum spp. tends to be high in this same reach and further downstream. Submersed aquatic plants have a significant areal extent in those pools (11, 12, 13, and 19) that have relatively large tracts of floating-leaved aquatic and marsh vegetation (Table 1). The submergent category goes to zero below Pool 19 (except for 1 hectare in Pool 25). Minor submersed aquatic beds were found in the lower pooled river by Klein et al. (1975), but it is not known to what extent the turbidity of the lower river precluded an accurate assessment from the air photos.

Schuyler (1980) has presented a list of the more common wetland plants in Pool 19 (Table 16). The composition of the aquatic and marsh flora is not uncommon in this reach of the river, for the species in the list have ranges, over which they are considered common, that cover Pool 19 (Muenscher, 1944). The ranges of the aquatic and marsh species of Table 16 fall within one of three generalized patterns in the contiguous United States: a northern range that includes the Midwest, an eastern range that extends from the northern to the southern U.S. border and from the Great Plains to the Atlantic, and a range that covers virtually the entire contiguous U.S. All of the three distribution ranges include Pool 8, and the majority of aquatic and marsh plants found to be common in Pool 8 (Table 14) are under the rubric of common in Pool 19 (Table 16).

The work of Klein et al. (1975) in Pool 24, 25, and 26 of the Mississippi and lower Illinois River, as noted above, found only limited beds of submersed aquatic plants. Klein et al. (1975) identified twenty species of aquatic and marsh plants, three of which were submergent aquatic species (Table 17). One of the aquatic and marsh vegetation species (Heteranthera limosa) is not considered common in this reach of the Mississippi River, while two other species (Echinodorus cordifolius and Ludwigia alternifolia) are common in the mid and lower Mississippi Valley but not further north (Muenscher, 1944). Heteranthera limosa is considered to be a local plant

of the Great Plains (Muenscher, 1944). The remaining plant species of Klein et al. (1975) have ranges that include Pool 8, and all of these remaining plant species are contained in the aquatic and marsh species list that was formed by combining the records of the aforementioned three recent surveys of Pool 8 (Sefton, 1976; Swanson, 1976; and Ziegler and Sohmer, 1977). Neither Heteranthera limosa, Ludwigia alternifolia nor Echinodorus cordifolius is found in the composite species list of the three studies for Pool 8. The difference in the number of aquatic and marsh plants between the combination of the three studies for Pool 8 and the study of Klein et al. (1975) (55 versus 20 species, respectively) is not directly comparable, because the influence of one significant factor, degree of sampling effort, cannot be adequately removed.

Sparks et al.(1979) have given evidence for a recent decline in aquatic and marsh vegetation in the lowest pools of the Mississippi River and the lower Illinois River. The explanation for this decline is largely sedimentation and the turbidity that accompanies sedimentation. The adverse effects of sedimentation and turbidity on aquatic and marsh vegetation are well documented for the Illinois River, and the discussion of how silt and its associated turbidity affect wetland vegetation is discussed under the Illinois Waterway.

The aquatic flora from Pool 3 to the confluence of the Ohio River is displayed in Figure 6 in a fashion that provides an indication of the productivity of different river reaches. Figure 6 includes submersed aquatic beds. Because of the previously mentioned problems with the reliability of the submersed plant data, the plotted information of Figure 6 that includes submersed aquatics is just a representation of what was found in the remote-sensing assessments. Pool 5A to 10 have high concentrations (judged relative to pool water surface area) of total aquatic plant coverage,and emersed and floating-leaved aquatic plant coverage. Pool 3 to 5,and 11 to 13 have median concentrations of both total, and emersed and floating-leaved plant coverage. Concentrations of total aquatic plant coverage are quite small in Pool 15, 20, 21, and 22, and in the open river below Dam 26. Medium to low concentrations of total aquatic plant coverage are found in the remaining pools (Pool 14, 16 to 19, and 24 to 26). The largest concentrations of submersed and free-floating aquatic plants that were identified in the remote-sensing studies were found in Pool 7 to 9; these same pools, as noted previously, have extensive areas of submersed aquatic plants. Pool 5A and 6 stand out in terms of their exceptionally high concentrations of emersed and floating-leaved aquatic plants. Below Dam 13, the largest pool (Pool 19) has the highest concentration of total aquatic plant coverage and the highest concentration of submersed and free-floating aquatic plants that were identified in the remote-sensing assessment.

The terrestrial herbaceous class of the remote-sensing studies probably contains most of the wetland plants that are not true aquatics, although it is expected that the marsh delineation has at least some overlap with the terrestrial herbaceous delineation (Minor et al., 1977; Hagen et al., 1977). The terrestrial herbaceous class between Dam 26 and Cairo is virtually all (98 percent of total area) within the category forbs. From Pool 11 to 26, forbs are less dominant in the terrestrial herbaceous

class (71 percent of total area), the Leersia oryzoides category is significant (14 percent of total area), and the "mixed grass" category accounts for most of the remaining area of the class.

The above terrestrial herbaceous categories,which were used in the study of the reach from Pool 11 to Cairo, are quite different from the categories that were used in the study of the reach from Pool 3 to 10. The dominant categories of the reach from Pool 3 to 10 and their respective percentages of total terrestrial herbaceous cover are: road side and levee grass-brush-forb mixture (19 percent), upland meadow (15 percent), grass (12 percent), and sedge meadow (10 percent). Species compositions of the wetland plants in the terrestrial herbaceous class can be obtained from the studies cited above for Pool 7 and 8, Pool 19, and Pool 24, 25, and 26 of the Mississippi River and lower Illinois River. Terpening et al. (1974) should be consulted for a listing of moist-soil plant species of the Middle Mississippi. Some of the moist-soil plants that are contained in the terrestrial herbaceous class (explicitly identified with a category or otherwise) are considered prime duck food plants on the Illinois River (Table 18).

The woody vegetation class is comprised mainly of the category "mixed lowland hardwoods of greater than twenty feet in height" over the reach from Pool 11 to 26 (94 percent of total woody vegetation area). This same mixed hardwood category is dominant in the reach above Dam 10 (83 percent of total area), and willows comprise the next largest class (9 percent of total area). Two categories are of approximately the same size for the reach between Dam 26 and Cairo, and together comprise eighty-one percent of total woody vegetation. The two categories are: cottonwood and/or tree willow of greater than twenty feet in height, and mixed lowland hardwoods of greater than twenty feet in height. The species composition of bottomland forests has been well described for the Middle Mississippi (Terpening et al., 1974) and Pool 24, 25, and 26 of the Mississippi River and lower Illinois River (Klein et al., 1975).

Illinois Waterway

The current status of the wetland plants of the Illinois River is well described in Bellrose et al. (1977) and Bellrose et al. (1979). These studies have also assessed both the manner in which the current status came about and the effects of the changes in wetland vegetation on the fish and wildlife resources of the Illinois River Valley.

Annual variations in the productivity of wetland vegetation in the Illinois River Valley were principally under the influence of water-level fluctuations during the period immediately following completion of the nine-foot channel project (Bellrose et al., 1979). The variability of total annual productivity was comprised of relatively large fluctuations in the productivity of aquatic and moist-soil plants and of lesser fluctuations in the more tolerant marsh species. The historical record illustrates that those bottomland lakes that had less connection to the river (and thus were more isolated from river water-level fluctuations) had better overall wetland vegetation productivity (Bellrose et al., 1979).

The importance of water-level fluctuations as a determinant of productivity was eventually superseded by the cumulative effects of a persistently high siltation rate. Siltation and its attendant turbidity have since virtually eradicated submersed and floating-leaved aquatic plants, and have been the prime contributors to a major reduction in the areal extent of marsh vegetation (Bellrose et al., 1977). Silt accumulation in the backwaters has converted former marsh cover to forest cover and seasonal mud flats (Bellrose et al., 1977). What persists of the aquatic and marsh vegetation is comprised of residual beds of three species that are highly tolerant of turbidity and fluctuating water levels: Scirpus fluviatilis (river bulrush), Polygonum coccineum (marsh smartweed), and Nelumbo lutea (American lotus) — (Bellrose et al., 1979). None of the species, under the existing environmental conditions, is a valuable source of duck food (Bellrose et al., 1979 — see also Table 18).

Turbidity levels and the rates of sedimentation have progressively risen during the current century (Bellrose et al., 1977). An acceleration of the sedimentation rate was experienced after the mid 1940s, and is apparently attributable to the concurrent increase in land devoted to open row crops in the drainage basin (Bellrose et al., 1979). Deforestation along tributary streams is probably an additional contributor to the sediment load increase of the Illinois River (Bellrose et al., 1979).

Jackson and Starrett (1959) examined the relationship between sedimentation and turbidity under a variety of environmental conditions in Lake Chautauqua, La Grange pool. The bottom of Lake Chautauqua is composed of a loose collection of fine, organic sediments that were deposited by floodwaters of the Illinois River. The major conclusions of the study, under ice-free conditions, are (Jackson and Starrett, 1959): (1) in unvegetated shallows (less than 4.8 feet), turbidity is a function of wind velocity; (2) in shallows with aquatic vegetation, the functional dependence between turbidity and wind velocity is virtually eliminated, and the basal turbidity at low wind speed is reduced, relative to the unvegetated case: (3) in deep water (greater than 5.8 feet), turbidity levels have little or no sensitivity to wind velocity; and (4) the activity of rough fish increases turbidity. When ice cover was present, turbidity was not responsive to wind velocity variations.

Ice cover, vegetation, and deep water effectively damp the transmission of wind-generated surface distrurbances to the potentially resuspendible bottom material. The presence of rooted aquatic vegetation may also help to hold the bottom material in place. In the absence of ice cover and vegetation, wind-generated water waves readily resuspend fine bottom material in shallow water. It was observed in a shallow area, under conditions of an absence of vegetation and ice, that an increase in wind speed from 10 to 34 miles per hour was accompanied by a rise in turbidity from approximately 200 to 700 Jackson turbidity units (Jackson and Starrett, 1959).

The effect of rough fish on the turbidity of a bottomland lake was assessed in a recent aeriel survey (Bellrose et al., 1977). It could be seen that about the fishes were local zones of turbid water that gave a mottled appearance to the overall lake surface.

Turbidity and siltation act synergistically on aquatic and marsh vegetation through optical and physical mechanisms. Turbidity affects the development of aquatic and marsh plants by limiting the intensity of light at a given depth, thus inhibiting photosynthesis at that depth within a water body. Silt deposited on the leaves of aquatic plants can interfere with light collection (Davis and Brinson, 1980). Furthermore, siltation creates a soft, "false" bottom that provides poor root anchorage against the buffeting action of the wind (Mills et al., 1966) and that is readily resuspended(and experienced as turbidity)by the wind and fish activity (Jackson and Starrett, 1959).

Under conditions similar to those examined by Jackson and Starrett (1959), the loss of aquatic and marsh vegetation is likely to lead to an increase in turbidity, which will tend to work against the reestablishment of the vegetation.

Portions of former aquatic and marsh vegetation beds become seasonally exposed mud flats, as sediment filled bottomland lakes and sloughs (Bellrose et al., 1977). Mud flats are sites for volunteer moist-foil plants, including valuable duck food species (Table 18). Mud flats are located at the edges of the backwaters and are exposed when water levels decline into the summer. Bottomland lakes and sloughs have been made shallow, with gentle bottom gradients, by the deposition of silt. Given such a bottom topography, relatively small changes in water levels translate into comparatively large exposures or inundations of mud flats. The responsiveness of mud flat areas to water-level fluctuations is a major contributor to the current annual variability in moist-soil plant production (Bellrose et al., 1979). The best production of moist-soil plants is experienced when low water levels persist during the growing season.

To augment productivity of moist-soil plants for waterfowl, increasing areas of backwaters have been placed under water-level management. Levees have been constructed to isolate the backwaters from the river and its water-level variations. Water levels are manipulated to insure the exposure of large tracts of mud flats, to lessen competition for moist-soil plants by timing the exposure of mud flats, and to make the summer growth available to waterfowl by reflooding the mud flats to an appropriate depth during the fall migration (Bellrose et al., 1979).

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Addendum

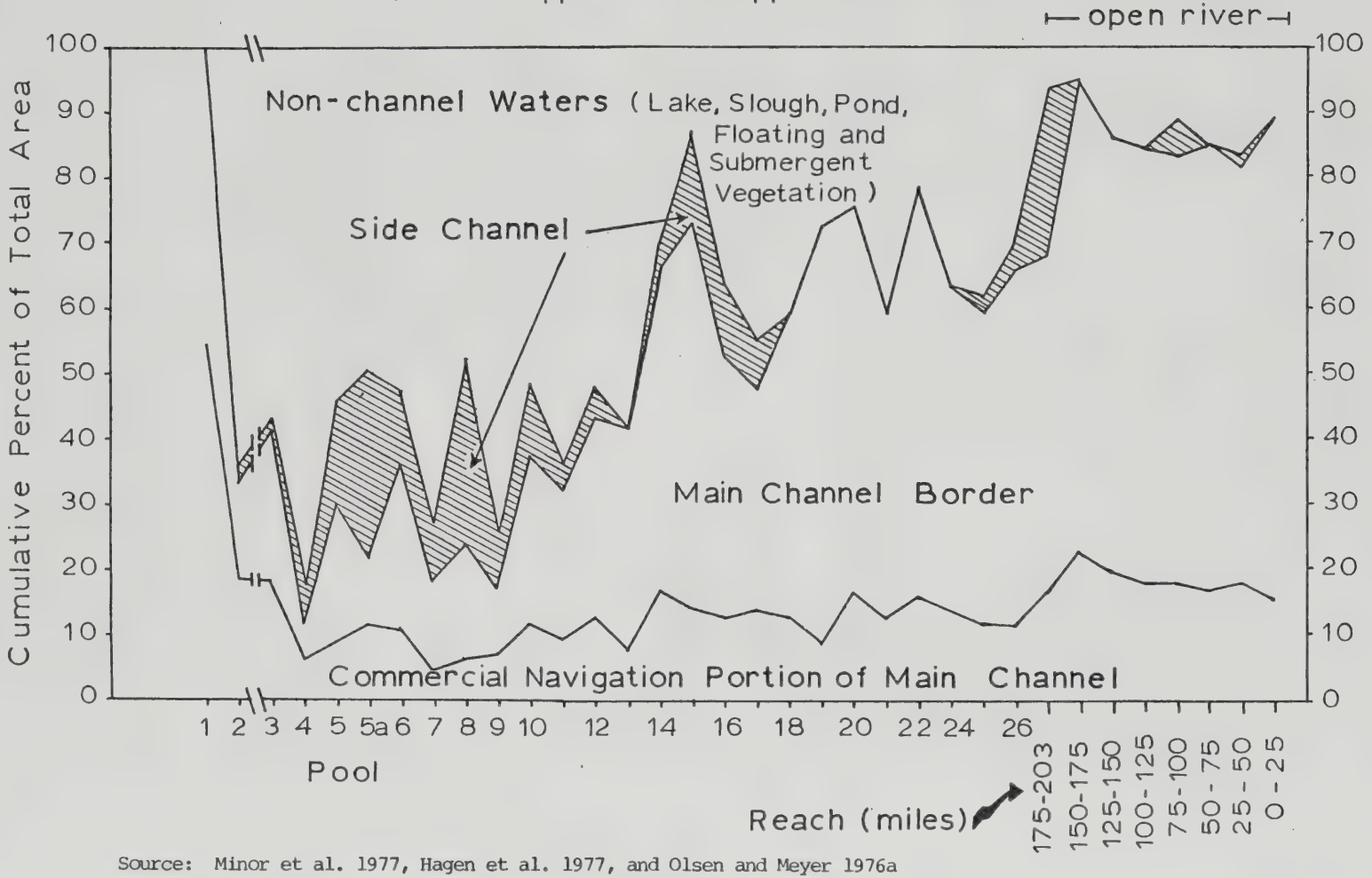
to

BIBLIOGRAPHY

Fuller (1978) published a final report in 1980. The 1980 report was not viewed during this study.

FIGURE 2

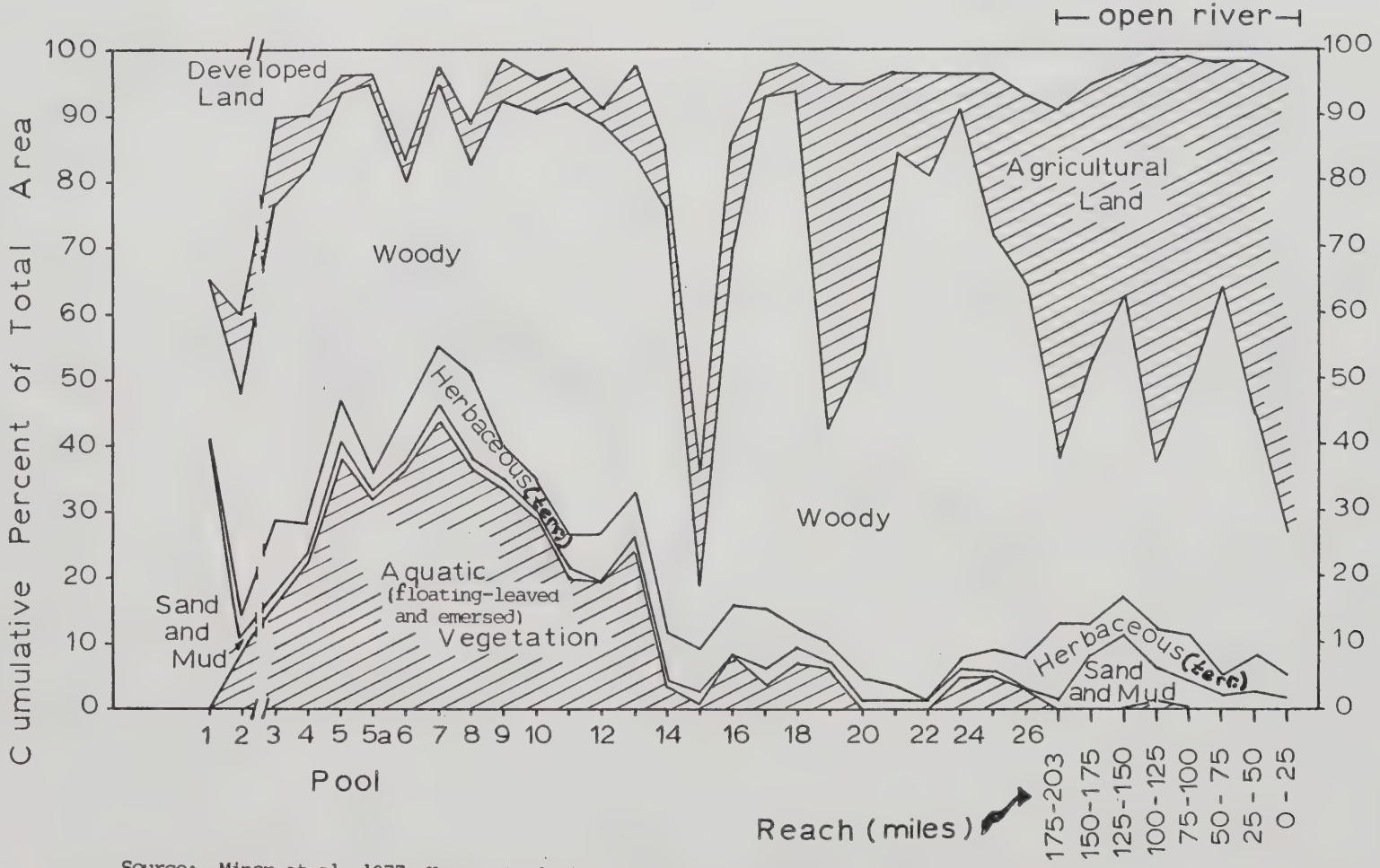
Relative Distribution of Water Types
on the Upper Mississippi River



Source: Minor et al. 1977, Hagen et al. 1977, and Olsen and Meyer 1976a

FIGURE 3

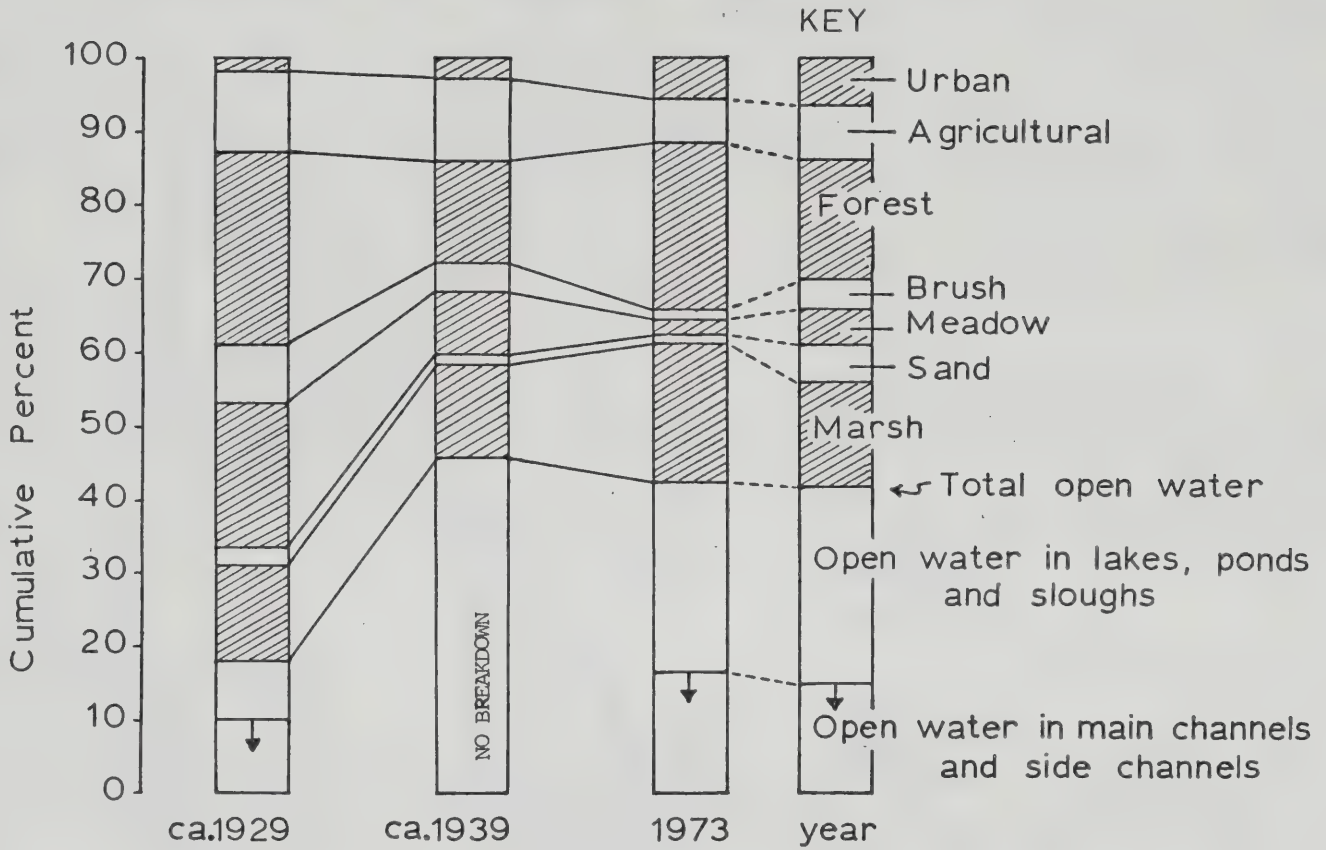
Relative Distribution of Floodplain Cover Types on the Upper Mississippi River



Source: Minor et al. 1977, Hagen et al. 1977, and Olsen and Meyer 1976a

FIGURE 4: Pool 5 to 10 land and water changes from pre-impoundment (ca. 1929) to early post-impoundment (ca.1939) to 1973.

Source: Olsen and Meyer 1976a, and Olsen and Meyer 1976b



(Total hectares inventoried: 1929 = 86,518; 1939 = 86,255; 1973 = 82,677)

Figure 5 : Land and Water Type Changes from Pre-Impoundment for the Nine-Foot Navigation Channel in the 1920s or 1930s to Post Impoundment in the 1970s. Upper Mississippi River and Illinois Waterway.
Sources: USAED 1977; USAED, SL, 1980.

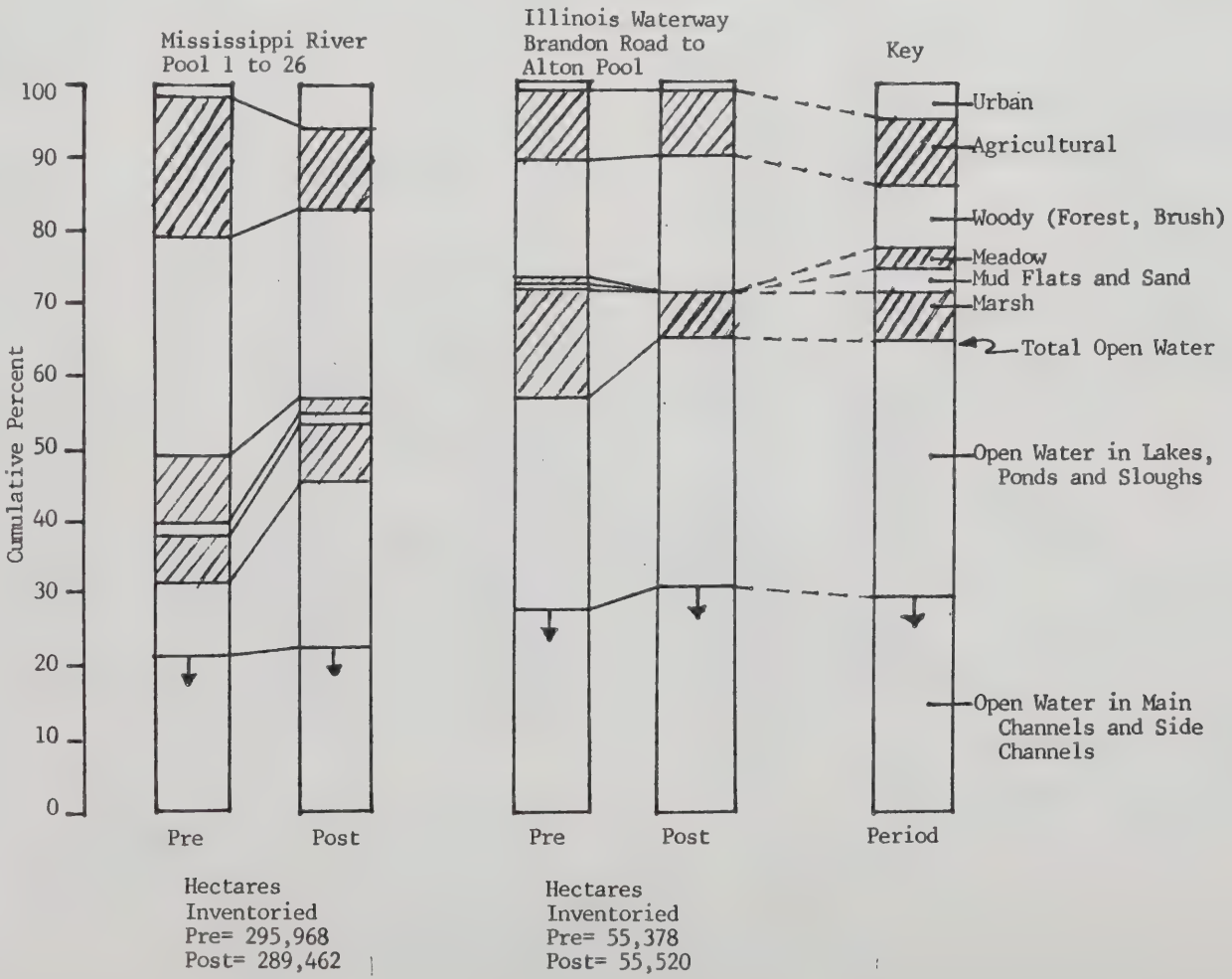


FIGURE 6

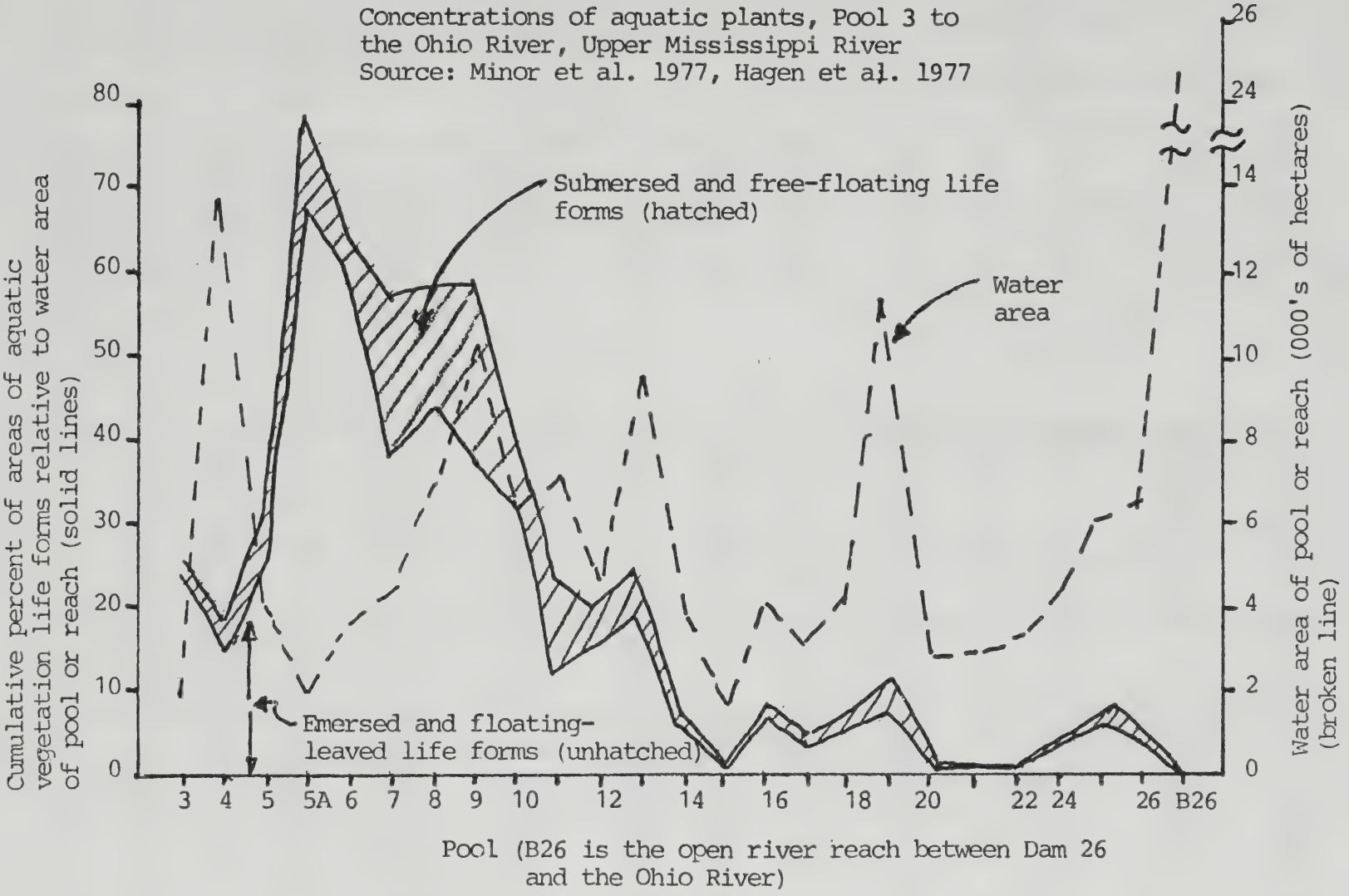

Concentrations of aquatic plants, Pool 3 to the Ohio River, Upper Mississippi River
Source: Minor et al. 1977, Hagen et al. 1977
Submersed and free-floating life forms (hatched)
Water area
Emersed and floating-leaved life forms (unhatched)
Cumulative percent of areas of aquatic vegetation life forms relative to water area of pool or reach (solid lines)
Water area of pool or reach (000's of hectares) (broken line)
0
10
20
30
40
50
60
70
80
0
2
4
6
8
10
12
14
24
26
3 4 5 5A 6 7 8 9 10 12 14 16 18 20 22 24 26 B26
Pool (B26 is the open river reach between Dam 26 and the Ohio River)

TABLE 1

Areas of water and floodplain cover types for the Upper Mississippi River (Minor et al., 1977 - Pool 3 to 10; Hagen et al., 1977 - Pool 11 to Cairo, Illinois; Olson and Meyer, 1976a - Pool 1 and 2)

Hectares (2.471 acres per hectare)

Pool[1]	Mch[2]	MchB	Sch	Non-ch	Water Subtotal	Ma	S&M	H	W	Ag	D	Land Subtotal	Total
1	119	97	0	0	216	0	19	0	11	0	16	46	262
2	728	624	52	2537	3941	318	68	231	1475	498	1741	4331	8272
3	398	481	32	1205	2116	510	32	388	1542	449	340	3261	5377
4	971	705	391	11549	13616	2081	202	570	5377	847	966	10043	23659
5	331	786	605	2066	3788	949	67	144	1169	65	110	2504	6292
5A	220	196	519	890	1825	1250	41	119	2293	43	161	3907	5732
6	309	713	302	1473	2797	1666	26	423	1544	128	802	4589	7386
7	243	646	373	3292	4554	1736	63	348	1598	118	101	3964	8518
8	530	1209	2015	3313	7067	3140	72	1110	2723	497	938	8480	15547
9	684	1125	801	7787	10397	3816	66	570	5854	767	107	11180	21577
10	728	1649	689	3214	6280	2166	47	373	4171	336	347	7440	13720
11	706	1678	206	4586	7176	862	64	244	2830	205	159	4364	11540
12	574	1330	170	2286	4360	637	16	277	2098	65	293	3386	7746
13[3]	751	3359	0	5432	9542	1835	96	496	3826	1014	227	7494	17036
14	662	1957	169	1172	3960	200	32	339	2856	443	604	4474	8497
15	220	864	187	187	1458	7	8	77	128	180	718	1118	2576
16	574	1783	461	1552	4370	329	16	321	2257	688	590	4199	8569
17	442	1127	176	1435	3180	113	109	362	3030	171	79	3864	7044
18	596	2077	0	1800	4473	280	89	134	3149	168	44	3864	8337
19	994	7327	36	3040	11397	826	128	519	5000	7704	767	14944	26341
20	486	1660	0	662	2808	14	49	116	1438	1194	107	2918	5726
21	397	1413	0	1166	2976	1	39	96	2894	414	121	3563	6539
22	530	2060	0	676	3266	6	27	50	2856	566	78	3583	6849
24	618	2151	0	1529	4298	170	35	80	2717	188	81	3271	7569
25	707	2928	72	2388	6095	411	31	349	5148	2076	209	8224	14319
26	839	3709	194	2020	6762	288	57	448	5556	2736	593	9678	16440
River Miles of Reach[4]													
175-203	618	1888	891	218	3615	4	82	691	1497	3133	544	5951	9566
150-175	552	1764	0	123	2439	0	321	188	1663	1760	209	4141	6580
125-150	552	1815	0	335	2702	9	632	359	2613	1926	181	5720	8422
100-125	552	2028	0	454	3034	98	568	741	3236	7689	100	12432	15466
75-100	552	2020	143	328	3043	2	198	406	2151	2677	70	5504	8547
50-75	552	2249	0	506	3307	0	114	161	2890	1688	61	4914	8221
25-50	552	2034	39	529	3154	13	182	358	2408	3439	83	6483	9637
0-25	552	2566	0	382	3500	0	210	444	2938	9117	466	13175	16675

[1] A pool has the same number as the dam that impounded it.

[2]
- Mch - commercial navigation portion of main channel water
- MchB - main channel border water
- Sch - side channel water
- Non-ch - non-channel water (lake, slough, pond, side stream, submergent and floating vegetation)
- Ma - floating-leaved aquatic and marsh vegetation
- S & M - sand and mud
- H - terrestrial herbaceous vegetation
- W - woody vegetation
- Ag - agricultural land
- D - developed, non-agricultural land (park and urban lands)

[3] Does not include uninventoried off-channel lands controlled by Savanna Proving Grounds

[4] Miles above the confluence of the Ohio River at Cairo, Illinois

TABLE 2

Relative Distribution of Water and
Floodplain Cover Types within Pool 9

(Minor et al., 1977)

Water
(percent)

	Mch[1]	McB	Sch	Non-ch	Row sum
Lower third	2.1	4.2	3.8	39.3	49.4
Middle third	2.3	3.3	1.4	19.2	26.2
Upper third	2.1	3.3	2.5	16.4	24.3
Column sum	6.5	10.8	7.7	74.9	99.9 (due to rounding)

Water hectares = 10,397

Lower third - river mile 648 to 658
middle third - river mile 658 to 669
upper third - river mile 669 to 679

Floodplain cover
(percent)

	Ma[2]	S&M	H	W	Ag	D	Row sum
Lower third	5.6	*	.4	1.9	0	.1	8.0
Middle third	18.0	.1	1.0	9.0	0	.2	28.3
Upper third	10.5	.5	3.8	41.4	6.9	.6	63.7
Column sum	34.1	.6	5.4	52.3	6.9	.9	100.0

* = less than .05 percent
Floodplain hectares = 11,180

[1] Mch - commercial navigation portion of main channel
MchB - main channel border
Sch - side channel
Non-ch - non-channel (lake, slough, pond, side stream, submergent and floating aquatic vegetation)

[2] Ma - floating-leaved aquatic and marsh vegetation
S & M - sand and mud
H - terrestrial herbaceous vegetation
W - woody vegetation
Ag - agricultural land
D - developed, non-agricultural land (park and urban lands)

TABLE 3

Areas of water and floodplain cover types for the lower Minnesota and lower St. Croix River (Olson and Meyer, 1976a), for Alton Pool, Illinois Waterway (USAED, SL, 1980) and for LaGrange to Brandon Road Pool, Illinois Waterway (Bellrose, et al. 1977)

Illinois Waterway

Hectares (2.471 acres per hectare)

Pool	Mch[1]	MchB	Sch	Non-ch	Tw	Water Subtotal	Ma	S&M[3]	Me	W	Ag	D	Land Subtotal	Total
Alton	1081	2223	257	2603	11	6175	971	10	2	6593	4767	582	12925	19100
La Grange	1583	762	154	9616	16	12131	1082	1870	0	1858	1	24	2965	15096
Peoria[2]	2138	6279	221	6097	29	14764	1004	829	0	1932	420	104	3460	18224
Starved Rock	292	765	149	69	15	1290	0	0	0	0	0	0	0	1290
Marseilles	470	253	56	145	26	950	4	0	0	4	198	0	206	1156
Dresden Island[4]	325	476	37	382	32	1252	59	0	0	19	0	0	78	1330
Brandon Road	98	74	0	1	8	181	4	0	0	35	0	0	39	220

Reach	Mch	MchB	Sch	Non-ch	Water Subtotal	Ma	S&M	Me	W	Ag	D	Land Subtotal	Total
Minnesota River	237	0	15	346	598	1108	16	820	996	367	660	3967	4565
St. Croix River	541	2684	0	32	3257	12	28	4	163	0	217	424	3681

TABLE 3 (continued)

[1] Mch - commercial navigation portion of main channel
MchB - main channel border
Sch - side channel
Non-ch - non-channel (lake and pond, and slough)
Tw - tail water
Ma - marsh vegetation
S&M - sand and mud
Me - meadow
W - woody vegetation
Ag - agricultural land
D - urban land

[2] Main channel and main channel border contain 6276 hectares of Peoria Lake.

[3] LaGrange and Peoria Pool areas in this category are mud flats of an intermittant and variable size and were assigned, for purposes in the original work, to other categories.

[4] Includes 359 hectares of Kankakee River channel to Wilmington.

TABLE 4

Distribution of Mussel Species in the Upper Mississippi River and Navigable Tributaries

Sources: Carlson 1968, Cawley 1973, Colbert et al. 1975, Dawley 1947, Elstad 1977, Freitag 1978, Fremling et al. 1979, Fuller 1978, Gale 1975, GREAT II - FWWG 1980, Grier 1922, Grunwald 1977a, Grunwald 1977b, Grunwald 1978a, Grunwald 1978c, Hall 1980, Havlik and Stansbery 1977, Johnson 1976, Lopinot 1977, Mathiak 1979, Morrison 1959, Finke 1966, Pagge and Schneider 1980, Perry 1979, Starrett 1971, Uhler 1929, van der Schalie and van der Schalie 1950.

TABLE 4 (continued)

Scientific name	Status[1]	Mississippi River Pool Numbers (the open river is referred to as B26---below Locks and Dam 26)																								Minn Riv.	St.Cr. Riv.	Illinois River Pool Numbers[3]			
		1	2	3	4	5[2]-6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	24	25	26	B26			6	7	8	4,5
Actinonaias carinata	J		▪		0	0	0	▪	X		▪			▪	X	X	▪	X	▪	X								X	0	0	0	0
A. ellipsiformis					0							X																			
Alasmidonta marginata	J				0	0	0	0			0																		0			0
A. viridis (calceola)	J					0																							0			
Amblema plicata	H		▪		▪	▪	▪	▪	X	X	▪	X	X	▪	X	X	▪	X	▪	▪	X	▪	▪	▪	X	▪	X	0	▪	▪	▪	▪	0
Anodonta grandis	H				▪	▪	▪	X	X	▪	▪	X	X	▪	X	▪	▪	X	▪	▪	X		X	X		▪	X	0	▪	▪	▪	▪	0
A. imbecillis	H				0	▪	0	X	0		▪	X	X			▪			▪				▪		0		0		▪	▪	▪	0
A. suborbiculata	T														X	0				X								0	▪	0	
Anodontoides ferussacianus	J				0											X												0			
Arcidens confragosus	T				0	▪					▪	X	X	▪	X	X	▪	X	▪	▪	X	X	X	X			0	X	0	▪	▪	▪	
Carunculina parva	H				▪	X	X		X	▪	▪	X		▪		X	X			▪	X						X	0		0	0	▪	
Cumberlandia mondonta	T									0						▪	▪	X		▪	X				X					0	0	
Cyclonaias tuberculata	J				0					0			0	X	0	▪												0	0	0	0	0
Dysnomia triquetra	J				0	0	0																	X					0			0
Ellipsaria lineolata	T				▪	▪	▪	▪	X	X	▪	X	X	▪	X	X	▪	X	▪	▪	▪	X	▪	▪	▪		▪	X	0	X	0	0	0	0
Elliptio crassidens	J				0	0	0	0	0		▪			0														X	0	0	0	0	0
E. dilatata			0		▪	0	▪		▪	X	▪	X	▪		X		X										0	X	0	0	0	0
Fusconaia ebena	J				0	0	▪	0	0	X	▪		0	X	▪	▪	X	0	0	X	▪	▪	▪	X					0	0	▪	0
F. flava	H		X	0	▪	▪	▪	X	X	X	▪	X	X	▪	X	X	▪	X	▪	▪	X	▪	▪	▪		▪		0	▪	▪	▪	▪	0
Lampsilis higginsi	E				0		0	▪	X		▪	X			X	X	X	X										▪	0	0	0	0	0
L. ovata	H		▪		▪	▪	▪	▪	▪	X	▪	X	X	▪	X	X	▪	X	▪	▪	X	X	X	X	X				0	X	0	0	0	0
L. radiata	H	0	▪		▪	▪	0	0	X	▪	▪	X	X		X													0	▪	▪	▪	0	0
L. teres	T				▪	0	▪			X	▪		0	X	X	0	X	0	▪	X	▪	0	▪	X	▪	▪	X	0		▪	▪	▪	0
Lasmigona complanata	T				0	0	0			X	▪	X	▪	X		X	X	0	X	X			0		0	X	0	▪	▪	▪	▪	0
L. compressa	J												X		X																	
L. costata	J				0	0					▪		0		0															0		0
Leptodea fragilis	H	0	▪		▪	▪	0		X	X	▪	X	X	▪	X	X	▪	X	▪	▪	▪	X	▪	▪	▪	X	▪	X	0	▪	▪	▪	0
L. leptodon											0			0																		
Ligumia recta	T		▪		▪	▪	▪	▪	▪	X	▪	X	X	▪	X	X	▪	X	▪	▪	▪	X		0	▪				0	0	0	0	0
L. subrostrata	J					0	0																									
Megalonaias gigantea	T				0	0		X		X	▪	X	X	▪	X	X	▪	X	▪	▪	▪	X		▪	▪	X	▪	X	0	0	▪	▪	▪	
Obliquaria reflexa	H				▪	▪	▪	▪	X	X	▪	X	X	▪	X	X	▪	X	▪	▪	▪	X	▪	▪	▪	X	▪	X	0	▪	0	▪	▪	0
Obovaria olivaria	H				▪	▪	▪	X	▪	X	▪	X	X	X	X	X	▪	X	▪	▪	X	▪	▪	▪		▪	X	0	X	0	0	▪	0
Plethobasus cyphyus	J				0	0	0	0			▪		0			▪	X	▪					0						0	0	0	0
Pleurobema cordatum	J		0		▪	0	▪	X	▪		▪		0														X	0	0	0	0	0
Proptera alata	T				▪	▪	▪	▪	X	X	▪	X	X	▪	X	X	▪	X	▪	▪	X	X	X	X		▪	X	0	▪	▪	▪	▪	
P. capax	E				0					0						0		0			0	0	▪		0					0	0	0
P. laevissima	H				▪	X	X	X			▪	X	X	X	X	X	X	▪	▪	X	0	▪			▪	X	0			▪	▪	▪	
P. purpurata	J																									X						
Quadrula metanevra	T		0	0	0	▪	▪	▪	X		▪	X	X	▪	X	X	▪	X	▪	X	X	▪	X	▪				X	0	0	0	0
Q. nodulata	H							X	X	X	▪	X	X	▪	X	X	▪	X	▪	▪	X	▪	▪	▪	X	▪	X			0	▪	▪	0
Q. pustulosa	H		0		▪	▪	▪	▪	X	X	▪	X	X	▪	X	X	▪	X	▪	▪	X	▪	X	▪		▪	X	0	▪	0	▪	▪	0
Q. quadrula	H		0	0	0			X	X	X	▪	X	X	▪	X	X	▪	X	▪	▪	X	▪	▪	▪		▪	X	0	X	▪	▪	▪	0
Simpsoniconcha ambigua	J									0																						
Strophitus undulatus	T		X		▪	▪	0	X	0		▪	X	X	▪	X	X	▪	X	0	0			X			▪			0	0	0		
Tritogonia verrucosa	J		0	0	0	0	▪	X	X	X	▪		X				▪	X	▪	▪		0	0	0		0		0	▪	0	0	0	0
Truncilla donaciformis	H				▪	▪	▪		X	X	▪	X	X	X	X	X	▪	X	▪	▪	X	▪	0	▪	X	▪	X	0	X	0	0	▪	0
T. truncata	H	0	▪		▪	▪	▪	X	X	X	▪	X	X	▪	X	X	▪	X	▪	X	X	X		▪	X	▪	X	0	▪	0	▪	▪	0
Villosa iris																																0

Period when identified: X = post 1964
0 = 1964 and before

[1] Status: H - Healty, T - Troubled, J - Jeapordized, E - Endangered

[2] Pools 5 and 5A are combined under the designation 5

[3] Pool 6 - Peoria Pool, Pool 7 - La Grange Pool, Pool 8 - Alton Pool, Pools 4,5 - Marseilles and Starved Rock Pool, respectively (included under Pools 4,5 is the lowest one mile of Pool 3 - Dresden Island Pool)

TABLE 5

Species counts from mussel surveys that presented sampling records for river reaches that are contained either within the navigation pools or within other commercially navigable river segments.

Sources: same as Table 4

Mississippi River

Pool[1]	Post 1964	1964 & before	Total
USAF[2]	0		0
LSAF[2]			
1	0	3	3
2	9	13	15
3		4	4
4	20	39	39
5[3]	20	33	35
6	20	30	32
7	22	15	27
8	23	10	28
9	23	2	23
10	34	40	40
11	26		26
12	26		26
13	25	29	33
14	27		27
15	29	5	31
16	31	29	34
17	29		29
18	22	27	27
19	26	20	28
20	23		23
21	17	16	20
22	17	16	22
24	23	21	26
25	10		10
26	16	21	21
B26[4]	19		19

Illinois River

Pool[5]			
4,5	0	33	33
6	13	38	38
7	18	39	39
8	20	37	37

Minnesota River[6]	0	23	23
St. Croix River[6]	23	16	26

NOTES

1 A pool has the same number as the dam that impounded it.

2 USAF, LSAF - Upper and Lower St. Anthony Falls Pool, respectively.

3 Pool 5 and 5A are combined under the designation 5.

4 B26 - the open river between Locks and Dam 26 and the confluence of the Ohio River at Cairo, Illinois.

5 Illinois River Pools 4,5 - Marseilles and Starved Rock Pool, respectively (included under Pools 4,5 is the lowest one mile of Pool 3 - Dresden Island Pool)
Pool 6 - Peoria Pool
Pool 7 - La Grange Pool
Pool 8 - Alton Pool

6 Commercial navigation reaches only: Minnesota River - below Shakopee, Minnesota; St. Croix River - below Stillwater, Minnesota.

TABLE 6

Population Distributions of Major Mussel Surveys

Survey Period	Upper Mississippi River 1977[1]		Upper Mississippi River 1930-31[2]		Illinois River 1966[3]	
Species	Percent[4]	Rank	Percent	Rank	Percent	Rank
Amblema plicata	35.58	1	7.03	3	62.40	1
Truncilla donaciformis	13.50	2	3.23	14	.02	18-22
Quadrula pustulosa	8.80	3	5.07	5-6	10.01	2
Q. quadrula	5.88	4	4.13	8	9.18	3
Obovaria olivaria	5.09	5	5.70	4	.02	18-22
Fusconaia flava	3.93	6	3.43	12	1.08	11
Quadrula nodulata	3.78	7	1.53	20	1.55	7
Obliquaria reflexa	3.18	8	3.27	13	1.15	10
Truncilla truncata	2.51	9	1.15	22	.24	15
Megalonaias gigantea	2.47	10	1.19	21	4.87	4
Carunculina parva	2.23	11	.09	33	.02	18-22
Anodonta imbecillis	1.98	12	2.67	18	.12	17
A. grandis	1.91	13	3.17	15	2.83	5
Elliptio dilatata	1.45	14	2.02	19	0	23-40
Proptera alata	1.40	15	3.82	10	.38	13
Lampsilis ovata	1.26	16	4.11	9	0	23-40
Leptodea fragilis	1.24	17	10.27	2	1.51	8
Proptera laevissima	.73	18	2.81	16	.99	12
Arcidens confragosus	.53	19	.10	31-32	1.84	6
Ellipsaria lineolata	.46	20	.41	28	0	23-40
Actinonaias carinata	.35	21	.72	25	0	23-40
Quadrula metanevra	.31	22	2.65	17	0	23-40
Lampsilis radiata	.27	23	4.91	7	.18	16
Liguma recta	.22	24	.68	27	0	23-40
Lampsilis teres	.21	25	14.03	1	1.25	9
Lasmigona complanata	.20	26	.90	24	.31	14
Strophitus undulatus	.18	27	1.00	23	0	23-40
Pleurobema cordatum	.13	28	.15	29	0	23-40
Tritogonia verrucosa	.08	29	5.07	5-6	0	23-40
Cumberlandia monodonta	.07	30	0	39-40	0	23-40
Elliptio crassidens	.06	31	.01	37-38	0	23-40
Lampsilis higginsi	.04	32	.04	35	0	23-40
Cyclonaias tuberculata	0	33-40	.03	36	0	23-40
Fusconaia ebena	0	33-40	3.63	11	.02	18-22
Plethobasus cyphyus	0	33-40	.12	30	0	23-40
Proptera capax	0	33-40	.09	36	0	23-40
Actinonaias ellipsiformis	0	33-40	.10	31-32	0	23-40
Alasmidonta marginata	0	33-40	.06	34	0	23-40
Simpsoniconcha ambigua	0	33-40	.01	37-38	0	23-40
Anodonta suborbiculata	0	33-40	0	39-40	.02	18-22
	100.03*		100.00		99.99*	

*due to rounding

1 Fuller, 1978 (figures include the navigable portion of the lower Minnesota and lower St. Croix River)

2 van der Schalie and van der Schalie, 1950.

3 Starrett, 1971.

4 Percent of total number of specimens collected.

Source	Total specimens collected
Fuller, 1978	8502
van der Schalie and van der Schalie, 1950	6786
Starrett, 1971	4247

TABLE 7

Gastropods of the Upper Mississippi River Identified in the Literature Survey for this Study (survey in Supplement A).

Scientific name	Pool in which collected
Amnicola binneyana	19
Amnicola lustrica	19
Amnicola sayana	19
Aplexa sp.	8
Campeloma crassula	19
Campeloma decisum	19
Campeloma subsolida	6, 9
Cincinnatia emarginata	Illinois River
Discus macClintocki	11-22
Fontigens nickliniana	19
Goniobasis sp.	25
Gyraulus parvus	9
Helisoma trivolvis	19
Laevapex fuscus	19
Lioplax subcarinata	19
Lioplax sulcosa	19
Lymnaea caperata	6
Lymnaea palustris	6
Menetus sp.	10
Physa anatina	19
Physa gyrina	6, 19
Physa integra	9

TABLE 7 (continued)

Planorbula sp.	1, 4
Pleurocera acuta	5, 10, 19
Somatogyrus depressus	19
Somatogyrus isogonus	19
Somatogyrus subglobosus	19
Stagnicola emarginata	8
Stagnicola caperata	5
Valvata sincera	4, 8
Valvata tricarinata	4, 8, 19
Viviparus georgianus	19
Viviparus intertextus	9

Sources: Carlander et al. 1969, Carlson 1968, Cawley 1973, Collingsworth 1973, Eckblad et al. 1977, Elstad 1977, Fremling et al. 1973a, Gale 1975, GREAT II-FWWG 1980, Grunwald 1978a, Grunwald 1978b, Johnson 1976, Mills et al. 1966, UMRWFR 1928.

TABLE 8

Oligochaetes of the Upper Mississippi River and of the Alton Pool of the Illinois River Identified in the Literature Survey for this study (survey in Supplement A).

Scientific name	Pool in which collected (Ill. - Illinois River, Alton Pool)
Branchuira sowerbyi	4,5,6,8,9,10,19,24,25,26,Ill.
Chaetoganter limnaei	19
Dero digitata	8, 24, 25, 26
Haplotaxis sp.	4
Ilyodrilus tempeltoni	8, 24, 25, 26, Ill.
Limnodrilus angustipenis	8, 24, 25, 26
Limnodrilus cervix	8, 24, 25, 26, Ill.
Limnodrilus claparedeianus	8, 10, 24, 25, 26, Ill.
Limnodrilus hoffmeisteri	8, 10, 19, 24, 25, 26, Ill.
Limnodrilus maumeensis	8, 24, 25, 26, Ill
Limnedrilus profundicula	8, 24, 25, 26, Ill.
Limnodrilus spiralis	8, 24, 25, 26, Ill.
Limnodrilus udekemianus	8, 10, 24, 25, 26, Ill.
Lumbriculus variegatus	8, 24, 25, 26
Nais barbata	8, 24, 25, 26
Nais communis	6, 8, 24, 25, 26, Ill.
Nais simplex	8, 24, 25, 26, Ill.
Peloscolex ferox	8, 24, 25, 26, Ill.
Peloscolex freyi	8, 24, 25, 26
Peloscolex multisetosus	8, 10, 24, 25, 26, Ill.
Peloscolex variegatus	8, 24, 25, 26, Ill.

TABLE 8 (continued)

Potamothrix vejdovskyi	8, 24, 25, 26, Ill
Pristina breviseta	8, 24, 25, 26
Pristina plumaseta	8, 24, 25, 26
Psammoryctides curvisetosus	8, 24, 25, 26, Ill.
Rhyacodrilus coccineus	8, 24, 25, 26, Ill.
Slavina appendulata	8, 24, 25, 26
Stylaria fossularis	26
Stylaria proboscidea	5
Tubifex ignotus	8, 24, 25, 26, Ill.
Tubifex tubifex	5, 10, 24, 25, 26, Ill.

Sources: Carlander et al. 1969, Carlson 1968, Cawley 1973, Colbert et al. 1975, Eckblad et al. 1977, Fremling et al. 1973d, Fremling et al. 1973c, Fremling et al. 1973a, Fremling et al. 1979, Gale 1975, Johnson 1976, Midwest Aquatic Enterprises 1975.

TABLE 9

Distribution and relative abundance of Upper Mississippi River fishes. A pool carries the same number as the dam that impounded it. The open river between Locks and Dam No. 26 and the confluence of the Ohio River at Cairo, Illinois is designated B-26. Source: Rasmussen, 1979.

Status of a species:

- X - Probably occurs in the pool only as a stray from a tributary water.
- H - Records of occurrence are available for this pool, but the species has not been recorded in UMRCC collections in the last ten years.
- R - Considered to be rare in this pool. Some species in this category may be on the verge of extirpation.
- U - Uncommon; does not usually appear in sample collections; populations are small, but the species in this category do not appear to be on the verge of extirpation.
- O - Occasionally collected; not generally distributed; local concentrations may occur.
- C - Commonly taken in most sample collections throughout the pool; can make up a large portion of some samples.
- A - Abundantly taken in all river surveys.

SPECIES	POOL NUMBER																									
	1	2	3	4	5	5A	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	24	25	26	B-26
Bull shark (Carcharhinus leucas)																									X		
Chestnut lamprey (Ichthyomyzon castaneus)				H	H			H	H	H	R	R	R								O	O	O	O	O	O	O
Silver lamprey (Ichthyomyzon unicuspis)					H	H		H	H	H	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	U
Lake sturgeon (Acipenser fulvescens)			H	H	R	H	H		H	H	H	R					R	H		H	H	R	H		R		
Pallid sturgeon (Scaphirhynchus albus)																											R
Shovelnose sturgeon (Scaphirhynchus platorynchus)				O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O
Paddlefish (Polyodon spathula)				R	R	R	R	R	R	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O
Spotted gar (Lepisosteus oculatus)																									X		
Longnose gar (Lepisosteus osseus)	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	O
Shortnose gar (Lepisosteus platostomus)	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	A
Alligator gar (Lepisosteus spatuala)																											R
Bowfin (Amia calva)	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C
American eel (Anguilla rostrata)			O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O
Alabama shad (Alosa alabamae)																											R
Skipjack herring (Alosa chrysochloris)				H		H	H		H	H	H			H		O	O	O	O	O	O	O	O	O	O	O	C
Gizzard shad (Dorosoma cepedianum)	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A
Threadfin shad (Dorosoma petenense)																											U
Goldeye (Hiodon alosoides)			H	H	H		H		H	R	H	H	U	H	H		U	U	U	O	C	C	C	C	C	C	C
Mooneye (Hiodon tergisus)	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	O	O	O	O	O	O	O
Rainbow trout (Salmo gairdneri)								X		X	X				X												
Mudminnow (Umbra limi)								X	X	X																	
Grass pickerel (Esox americanus)										X	X				X			X	X						X	X	
Northern Pike (Esox lucius)	C	C	C	C	C	C	C	C	C	C		O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	
Muskellunge (Esox masquinongy)	H	H	H	H	H	H	H	H	H	H																	
Stoneroller (Campostoma anomalum)				X				X	H	H	X	X					X	H		X		X	X	X	X	X	X
Ozark minnow (Dionda nubila)																											X
Carp (Cyprinus carpio)	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A
Grass carp (Ctenopharyngodon idella)																O		O			O		O	O	O		O
Silverjaw minnow (Ericymba buccata)																											X
Western silvery minnow (Hybognathus argyritis)																											O
Brassy minnow (Hybognathus hankinsoni)	H		H	H			R	R		H																	
Silvery minnow (Hybognathus nuchalis)			H	C	C	C	C	C	C	C	C	C	C	C	C												
Plains minnow (Hybognathus placitus)																											C
Speckled chub (Hybopsis aestivalis)				C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C
Sturgeon chub (Hybopsis gelida)																											R

TABLE 9 (continued)

SPECIES	POOL NUMBER																											
	1	2	3	4	5	5A	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22,24	25	26	B-26
Flathead chub (Hybopsis gracilis)																										A
Sicklefin chub (Hybopsis meeki)																										U
Silver chub (Hybopsis storeriana)	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C
Gravel chub (Hybopsis x-punctata)																										R
Hornyhead chub (Nocomis biguttatus)	C			X																						
Golden shiner (Notemigonus crysoleucas)			H	O		H	H	H	H	O	O	H	O	O	O	H	H	O	O	O	H	O		O	O	O
Pallid shiner (Notropis amnis)			H	H	H	H		R	H	H	R	H		R								H				
Pugnose shiner (Notropis anogenus)				X																						
Emerald shiner (Notropis atherinoides)	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A
River shiner (Notropis blennius)	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	C
Bigeye shiner (Notropis boops)																						X				X
Ghost shiner (Notropis buchanani)	H	H	H	H	H	H	H	H	H	H	H	R	R	R	O	C	C	C	C	C	C	C	C	C	C	C
Striped shiner (Notropis chrysocephalus)																										X
Common shiner (Notropis cornutus)	O								H	H	H	H														
Bigmouth shiner (Notropis dorsalis)	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	H
Pugnose minnow (Notropis emiliae)	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O							
Spottail shiner (Notropis hudsonius)	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	O
Red shiner (Notropis lutrensis)																			C	C	C	C	C	C	C	C
Rosyface shiner (Notropis rubellus)							X			H		X														
Silverband shiner (Notropis shumardi)																								O	O	C
Spotfin shiner (Notropis spilopterus)	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	O	O	O	O	O		X
Sand shiner (Notropis stramineus)	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O
Weed shiner (Notropis texanus)				U	U	U	U	U	U	U	U	U														
Blacktail shiner (Notropis venustus)																										X
Mimic shiner (Notropis volucellus)			H	H	H	H	H	H	H	H	H	H														
Suckermouth minnow (Phenacobius mirabilis)					H	H			H	H	H	H		U		U	U		U	U		U	U	U	U	U
Southern redbelly dace (Phoxinus erythrogaster)												X														
Bluntnose minnow (Pimephales notatus)	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O
Fathead minnow (Pimephales promelas)	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U
Bullhead minnow (Pimephales vigilax)				A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	C
Creek chub (Semotilus atromaculatus)			X	X	H				X	X	H	H												X		
Pearl dace (Semotilus margarita)	X																									
River carpsucker (Carpiodes carpio)	O	O	O	O	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	A
Quillback (Carpiodes cyprinus)	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	O
Highfin carpsucker (Carpiodes velifer)	O	O	O	O	O	O	O	O	O	O	O	O	O	O					U	U						
White sucker (Catostomus commersoni)	C	C	C	C	C	C	C	C	C	C	C	C		X	X	X	X			X	X	X		X	X	X	X
Blue sucker (Cycleptus elongatus)				U	H	H	H	H	H	R	H	H			U	H	H			U	U	H		H	H	U	U
Northern hog sucker (Hypentelium nigricans)				R	R	R	R	R	R	R	R	R	R			X	X			X						X
Smallmouth buffalo (Ictiobus bubalus)	R	R	R	R	R	R	R	R	R	R	R	R	R	C	C	C	C	C	C	C	C	C	C	C	C	C
Bigmouth buffalo (Ictiobus cyprinellus)	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C
Black bufflao (Ictiobus niger)				H	H	H	H	R	H	R	H	H	H	R	C	C	C	C	C	C	C	C	C	C	C	C
Spotted sucker (Minytrema melanops)				O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	U							
Silver redhorse (Moxostoma anisurum)	U		H	U	U	U	U	U	U	U	U	U	R	R	R	R	R	R	R	R	R					R
River redhouse (Moxostoma carinatum)									R		H															
Golden redhorse (Moxostoma erythrurum)			H	U	U	U	U	U	U	U	U	U	U	U	R	R	R	R	R	R	R			R		R
Shorthead redhorse (Moxostoma macrolepidotum)	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	U	U
Greater redhorse (Moxostoma valenciennesi)					H				H																	
White catfish (Ictalurus catus)																	X									
Blue catfish (Ictalurus furcatus)														H	H	H	H	H	H	H	H	H	H	H	H	O
Black bullhead (Ictalurus melas)	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O
Yellow bullhead (Ictalurus natalis)		O	H	O	O	O	O	O	O	O	O	O	O	O			O	O	O	O	O	O		O	O	O
Brown bullhead (Ictalurus nebulosus)		H	H	H	H		H		H	H															X	
Channel catfish (Ictalurus punctatus)	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C
Stonecat (Noturus flavus)				H			H			H	H	H		U			H				O	O			O	O
Tadpole madtom (Noturus gyrinus)			U	U		H	H	H	H	U	H	U	U	U	U					U		H			U	U

TABLE 9 (continued)

SPECIES	POOL NUMBER																										
	1	2	3	4	5	5A	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	24	25	26	B-26
Freckled madtom (Noturus nocturnus)																					U	U					
Flathead catfish (Pylodictis olivaris)	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C
Private perch (Aphredoderus sayanus)					X	X	X	X	X	X		H															
Trout-perch (Percopsis omiscomaycus)	O	O	O	C	O	O	O	O	O	O	O								U								H
Burbot (Lota lota)			H	H	H				H	H	H	H					R								H		
Northern studfish (Fundulus catenatus)																											X
Blackstripe topminnow (Fundulus notatus)																		U	U		O	O	O	O	O	O	O
Starhead topminnow (Fundulus notti)																									X		
Blackspotted topminnow (Fundulus olivaceus)																											X
Mosquitofish (Gambusia affinis)																								O	O	O	O
Brook silverside (Labidesthes sicculus)			C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	O	O	O	O			O	O
Mississippi silverside (Menidia audens)																											H
Brook stickleback (Culaea inconstans)			H	X				X																			
White bass (Morone chrysops)	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C
Yellow bass (Morone mississippiensis)				H			O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O
Rock bass (Ambloplites rupestris)	C	C	C	C	C	C	C	C	C	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	
Flier (Centrarchus macropterus)																											X
Green sunfish (Lepomis cyanellus)		O	H	O	O	H	O	O	O	O		O	O	O	O	O	O	O	O	O	O	O	O		O	O	O
Pumpkinseed (Lepomis gibbosus			C	C	C	C	C	C	C	C	C	C	C	C	C		H	H	U	H							
Warmouth (Lepomis gulosus)			H				U	U	U	U	U	U	U	U	U		U	U	U			U	U	U	U	U	U
Orangespotted sunfish (Lepomis humilis)			C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C
Bluegill (Lepomis macrochirus)	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A
Longear sunfish (Lepomis megalotis)																											X
Redear sunfish (Lepomis microlophus)																									X		
Smallmouth bass (Micropterus dolomieui)	O	O	O	O	O	O	O	O	O	U	U	U	U	U	U	U	U	U	R	R	R	R	R	R	R	R	R
Spotted bass (Micropterus punctulatus)																											X
Largemouth bass (Micropterus salmoides)	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C
White crappie (Pomoxis annularis)	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C
Black crappie (Pomoxis nigromaculatus)	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C
Crystal darter (Ammocrypta asprella)							H		H			H															
Western sand darter (Ammocrypta clara)				O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	
Mud darter (Etheostoma asprigene)				H	H	H	H	H	H	H	H	H		O													O
Rainbow darter (Etheostoma caeruleum)							H																		X		
Bluntnose darter (Etheostoma chlorosomum)									H	H																	X
Iowa darter (Etheostoma exile)					X	H		X	X	X	H																
Fantail darter (Etheostoma flabellare)			H	X							X	H														X	X
Johnny darter (Etheostoma nigrum)	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U		U	U		U	U	U	U		U
Orangethroat darter (Etheostoma spectabile)																									X		X
Banded darter (Etheostoma zonale)										X	X	X															
Yellow perch (Perca flavescens)	C	C	C	C	C	C	C	C	C	C	C	C	O	O	O	O	O	O	O	O			H				
Log perch (Percina caprodes)		C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C			O	O	O	O		U	U
Blackside darter (Percina maculata)				X	X				X	X	X															X	
Slenderhead darter (Percina phoxocephala)				H	H		H	H	H	H		H									R	R			R	R
Dusky darter (Percina sciera)																											X
River darter (Percina shumardi)		C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	U
Sauger (Stizostedion canadense)	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C
Walleye (Stizostedion vitreum)	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	O	O	O	O	O	O
Freshwater drum (Aplodinotus grunniens)	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	A
Banded sculpin (Cottus carolinae)																											X

TABLE 10

Composition of the Catch Obtained by Hoop Netting in Three Illinois River Fish Surveys (taken from Bellrose et al., 1977)

Species	Pre-1939 Number	Pre-1939 %	1942 Number	1942 %	1957-1967 Number	1957-1967 %
Longnosed Gar	43	0.03	107	0.36	23	0.11
Shortnosed Gar	1,903	1.26	599	1.99	475	2.33
Bowfin	346	0.23	136	0.45	20	0.10
Goldeye			30	0.10	4	0.02
Mooneye	35	0.02	17	0.06	1	0.01
Gizzard Shad	5,916	3.92	1,135	3.77	5,865	28.78
American Eel	29	0.02	38	0.13	1	0.01
Redmouth Buffalo	472	0.31	328	1.09	52	0.26
Black Buffalo	28	0.02	16	0.05	8	0.04
Smallmouth Buffalo	60	0.04	107	0.36	66	0.32
Carpiodes spp.	827	0.55	448	1.49	698	3.43
*Creek Chubsucker	75	0.05	27	0.09		
White Sucker	51	0.03			209	1.03
*Spotted Sucker	4	0.00	5	0.02		
Blue Sucker	237	0.16	259	0.86		
Northern Hogsucker	1	0.00	2	0.01	1	0.01
Silver Redhorse	5	0.00	6	0.02	1	0.01
Shorthead Redhorse	108	0.07	176	0.58	111	0.54
Carp	10,093	6.69	4,472	14.85	3,152	15.47
Goldfish	3	0.00	1,477	4.90	3,004	14.74
Carp-Goldfish Hybrid	1	0.00	197	0.65	469	2.30
Golden Shiner	75	0.05	114	0.38	37	0.18
Channel Catfish	1,568	1.04	819	2.72	13	0.06
Blue Catfish			4	0.01		
Yellow Bullhead	597	0.40	37	0.12	12	0.06
Brown Bullhead	1,169	0.77	86	0.29	26	0.13
Black Bullhead	2,421	1.60	1,900	6.31	2,672	13.11
Flathead Catfish	29	0.02	43	0.14	2	0.01
Northern Pike	3	0.00	1	0.00	1	0.01
White Crappie	15,489	10.26	3,616	12.01	1,260	6.18
Black Crappie	87,989	58.29	6,573	21.82	1,451	7.12
Warmouth	270	0.18	87	0.29	7	0.03
Green Sunfish	622	0.41	138	0.46	76	0.37
Orange-Spotted Sunfish	243	0.16	28	0.09	13	0.06
Bluegill	16,847	11.16	5,060	16.80	455	2.23
Pumpkinseed	1,137	0.75	767	2.55	8	0.04
Sunfish Hybrids	78	0.05	58	0.19	13	0.06
Largemouth Bass	711	0.47	263	0.87	12	0.06
Smallmouth Bass	4	0.00				
Walleye	2	0.00	3	0.01		
Sauger			39	0.13	1	0.01
White Bass	86	0.06	173	0.57	78	0.38
Yellow Bass	1,089	0.72	226	0.75	7	0.03
Yellow Perch	113	0.07	65	0.22	6	0.03
Freshwater Drum	129	0.09	414	1.37	62	0.30
Others	30	0.02	23	0.08	6	0.30
Total	150,938	100%	30,119	100%	20,378	100%

*Fish species extirpated from the Illinois River between 1908 and 1970 (Starrett, 1972).

TABLE 11

Average Number of Fish, by Species, Taken Per 30 Minutes of Electrofishing in Each Navigation Pool of the Illinois River, 1959-1974
Source: Sparks, 1975.

Species	Des Plaines River	Illinois River Pools					
	Dresden Pool	Marseilles	Starved Rock	Peoria	La Grange	Alton	Relative %**
Shortnose gar	0.00	0.00	0.00	0.05	0.07*	0.07*	0.05
Bowfin	0.00	0.00	0.00	0.01	0.02	0.07*	0.03
Gizzard shad	2.66	12.52	9.22	63.20*	43.55	18.09	39.18
Goldeye	0.00	0.03	0.00	0.02	0.02	0.41*	0.13
Mooneye	0.00	0.00	0.00	0.01	0.00	0.05*	0.02
Goldfish	42.76*	12.02	17.02	0.73	0.37	0.00	8.06
Carp x goldfish	1.05	0.80	2.02*	1.39	0.18	0.01	1.18
Carp	12.06	14.29	18.92	18.67	34.69*	19.81	28.44
River carpsucker	0.00	0.04	0.34	0.44*	0.39	0.27	0.40
Quillback carpsucker	0.00	0.71	1.38*	0.52	0.16	0.11	0.77
Smallmouth buffalo	0.00	0.03	0.25	0.67	1.04*	0.11	0.56
Bigmouth buffalo	0.00	0.01	0.05	5.79*	4.21	0.33	2.78
Black buffalo	0.00	0.00	0.02	0.19	0.24*	0.04	0.13
Shorthead redhorse	0.34	0.05	0.14	0.09	0.21	0.08	0.15

TABLE 11 (continued)

Black bullhead	0.00	4.39*	0.38	0.35	0.12	0.00	1.40
Yellow bullhead	0.00	0.00	0.00	0.07	0.10*	0.01	0.05
Channel catfish	0.00	0.01	0.34	0.17	1.60	3.76*	1.57
Flathead catfish	0.00	0.00	0.00	0.00	0.09	0.19*	0.07
White Bass	0.00	0.07	0.44	0.64	0.42	2.65*	1.13
Green Sunfish	0.23	1.01	0.65	2.91*	1.77	0.52	1.83
Bluegill	0.00	0.33	0.06	3.10	7.12*	4.90	4.15
Largemouth Bass	0.00	0.47	0.13	2.82	4.23*	1.70	2.50
White crappie	0.00	0.32	0.05	1.47	1.75*	1.07	1.25
Black crappie	0.00	0.04	0.18	2.44	5.55*	2.99	2.99
Freshwater drum	0.00	0.14	0.03	0.34	2.49*	1.49	1.20

* Indicates the pool or pools where the maximum number of individuals of each species was taken in the period 1959-1974

100.02 (due to rounding)

** Relative to all species for the Illinois River

TABLE 12

Waterfowl that are Relatively Abundant in the Upper Mississippi River Valley and Illinois River Valley

I. Abundant or common waterfowl species of the Upper Mississippi River Wildlife and Fish Refuge (UMRWFR) or of the lower reach of the GREAT II area.

Sources: adapted from GREAT I, FWWG, 1979; and GREAT II, FWWG, 1980.

Abundance Key:

A - abundant (present in large numbers)

C - common (certain to be seen but seldom in large numbers)

** - abundance for portion of GREAT II study area below UMRWRF (Pool 15 to 22) -- UMRWFR is Pool 4 to 15

Species	Abundance
Whistling Swan (Cygnus columbianus)	C, O **
Canada Goose (Branta canadensis)	C
Snow Goose (Anser caerulescens caerulescens)	U, C **
Mallard (Anas platyrhynchos platyrhynchos)	A
Black Duck (Anas rubripes)	C
Gadwall (Anas strepera)	C
Pintail (Anas acuta acuta)	A
Green-winged Teal (Anas crecca carolinensis)	C
Blue-winged Teal (Anas discors)	A
American Wigeon (Anas americana)	A
Northern Shoveler (Anas clypeata)	C
Wood Duck (Aix sponsa)	C
Redhead (Aythya americana)	C
Ring-necked Duck (Aythya collaris)	A

TABLE 12(continued)

Species	Abundance
Canvasback (Aythya valisineria)	C
Greater Scaup (Aythya marila mariloides)	A, R **
Lesser Scaup (Aythya affinis)	A
Common Goldeneye (Bucephala clangula americana)	C
Ruddy Duck (Oxyura jamaicensis rubida)	C
Hooded Merganser (Mergus cucullatus)	C
Common Merganser (Mergus merganser americanus)	C

II. Use-days by the more important species of waterfowl in the Illinois River Valley, October 1-December 1, 1944, 1972, 1975 and 1976 (Bellrose et al., 1977).

Species	1944	1972	1975	1976
Mallard	56,509,768	9,008,321	18,617,900	16,350,810
Black Duck	454,895	280,406	432,565	259,350
Pintail	1,445,598	76,146	623,756	432,411
Green-winged Teal	32,494	65,800	488,831	261,065
Blue-winged Teal	117,999	37,265	69,160	115,815
American Wigeon	811,335	227,255	887,845	887,411
Gadwall	31,493	13,489	83,251	42,126
Northern Shoveler	13,489	1,575	68,166	29,855
Lesser Scaup	10,330,970	354,550	216,195	129,045
Ring-necked Duck	1,523,431	89,341	90,685	50,715
Canvasback	190,885	4,998	33,565	13,321
Ruddy Duck	159,663	18,396	23,051	10,416
Common Goldeneye	2,667	4,830	5,880	30,821
Common Merganser	560	7,000	12,930	14,945
Total Ducks	71,625,247	10,189,372	21,653,780	18,613,161
Canada Goose	210	75,358	444,416	441,756
Snow Goose	1,001	225,988	278,635	252,945

TABLE 13

Dominant Categories of Aquatic and Marsh Vegetation
(each category is one of top four in a pool)
Source: Minor et al., 1977

Figures are percent of total hectares

Pool	Category								Summed Percent	Total Hectares[2]
	Sal[1]	Sc	N	Ny	10	17	19	22		
3	14	32	6					24	76	544
4	19	17			11			13	60	2409
5	31		7		17		18		73	1210
5a	28	13			20			7	68	1428
6	9	12		31				14	66	1805
7		14			8		25	12	59	2596
8	23	9			12		17		61	4163
9	23		9			8	28		68	6111
10	22	10			22			8	62	2525
3 to 10	20	10	6	4	11	6	17	7	81	22791

[1]Sal---*Sagittaria latifolia*
Sc---*Scirpus sp.*
N---*Nelumbo sp.*
Ny---*Nymphaea sp.*
10---*Nymphaea-Ceratophyllum-Potamogeton*-Lemnaceae
17---Lemnaceae-*Ceratophyllum-Potamogeton*
19---*Vallisneria-Potamogeton-Heteranthra*
22---*Scirpus-Sagittaria latifolia*

[2]Hectares of aquatic and marsh vegetation

TABLE 14

Summer frequency and biomass of vascular hydrophytes in Pools 7 and 8, Upper Mississippi River

	Pool 8[1]		Pool 7, 8[2]
	Frequency (%)	Biomass (%)	Biomass (%)
Sagittaria latifolia	11.57	45.24	NI
Vallisneria americana	9.19	14.33	3.04
Sagittaria rigida	4.46	8.50	NI
Ceratophyllum demersum	18.66	5.57	17.42
Potamogeton nodosus	6.21	5.10	32.51
Nymphaea tuberosa	3.76	4.60	0
Nelumbo pentapetala	3.58	4.32	20.81
Lemnaceae	5.64	3.39	2.55
Heteranthera dubia	5.03	1.36	4.40
Potamogeton crispus	8.19	1.17	1.55
Potamogeton pectinatus	6.58	1.14	0
Scirpus validus	.24	1.11	NI
Elodea canadensis	7.37	.78	15.12
Sagittaria rigida forma fluitans	1.61	.63	.02
Nuphar variegatum	.35	.60	0
Sparganium eurycarpus	.25	.58	NI
Potamogeton foliosus	3.28	.32	.28
Polygonum coccineum	.24	.28	NI
Potamogeton richardsonii	.65	.23	0
Potamogeton zosteriformis	1.41	.11	2.07
Myriophyllum exalbescens	.17	.0006	.23
Other species	1.59	.64	0

NI - not included in original work

[1]Sefton, 1976

[2]Sohmer, 1975 - does not include emergent species in the original work

TABLE 15

Dominant Categories of Aquatic and Marsh Vegetation
(each category is one of top three in a pool or reach)
Source: Hagen et al., 1977

Figures are percent of total hectares

Pool or Reach	Category										Summed Percent	Total Hectares[2]
	Sb[1]	7	Lm	N	6	Sa	Sc	J	Py	E		
11	39				26	18					83	1645
12	18				26	34					78	879
13	22			31		22					75	2416
14				14		61	13				88	220
15	17	13				70					100	10
16			11	44		38					93	369
17			11	18					51		80	127
18			6	64		25					95	301
19	33				15	24					72	1348
20			5	9			86				100	15
21			32			19				49	100	2
22			22	47		17					86	8
24				58		25			3		86	174
25			4					5	90		99	428
26				39		5			48		92	295
B26[3]				18				3	76		97	129
11 to B 26	21	2	3	21	12	23	5	*	10	*	98	8366

* less than .5 percent

[1]Sb---submergent aquatics
7---submergent aquatics and duckweed
Lm---duckweeds (Lemnaceae)
N---*Nelumbo lutea*
6---*Nelumbo lutea* and duckweeds
Sa---*Sagittaria* spp. (primarily *latifolia*)
Sc---*Scirpus fluviatilis*
J---*Jussiaea* sp.
Py---*Polygonum* spp.
E---*Eragrastis* spp.

[2]Hectares of aquatic and marsh vegetation

[3]Dam 26 to confluence of Ohio River at Cairo, Illinois

TABLE 16

Common Wetland Plants Observed in Pool 19

Source: Schuyler, 1980

Amaranthus tuberculatus
Asclepias incarnata
Bidens cernua
Ceratophyllum demersum
Echinochloa walteri
Elodea nuttallii
Heteranthera dubia
Hibiscus militaris
Lemna minor
Leersia oryzoides
Najas guadalupensis
Najas minor
Nelumbo pentapetala (lutea)
Polygonum amphibium
Polygonum hydropiperoides
Polygonum orientale
Polygonum punctatum
Potamogeton crispus
Potamogeton nodosus
Potamogeton pectinatus
Rumex verticillatus
Sagittaria latifolia
Scirpus fluviatilis
Scirpus tabernaemontanii (validus)
Sparganium eurycarpum
Spirodela polyrhiza
Typha spp.
Vallisneria americana
Zannichellia palustris

TABLE 17

List of Aquatic and Marsh Vegetation Species for Pools 24, 25 and 26 of the Mississippi River and Illinois River

Source: Klein et al., 1975.

Alisma planto-aquatica
Ceratophyllum demersum
Echinodorus cordifolius
Eleocharis obtusa
Heteranthera limosa
Lemna minor
Linderia dubia
Ludwigia alternifolia
Nelumbo lutea (pentapetala)
Polygonum coccineum
Polygonum hydropiperoides
Polygonum punctatum
Potamogeton pectinatus
Sagittaria graminea
Sagittaria latifolia
Scirpus validus
Sium sauve
Spartinia pectinata
Spirodela polyrhiza
Typha latifolia

TABLE 18

Duck Food Plants of the Illinois River Valley

Source: Bellrose and Anderson, 1943

EXCELLENT DUCK FOOD SOURCES

1. Rice cut-grass, Leersia oryzoides
2. Walter's millet, Echinochloa walteri
3. Wild and Japanese millets, Echinochloa crusgalli
4. Moist-soil smartweeds
   a. Largeseed smartweed, Polygonum pennsylvanicum
   b. Nodding smartweed, Polygonum lapathifolium
   c. Swamp smartweed, Polygonum hydropiperoides
   d. Miscellaneous, Polygonum spp.
5. Nutgrasses
   a. Chufa, Cyperus esculentus
   b. Red-rooted cyperus, Cyperus erythrorhizos
   c. Straw-colored cyperus, Cyperus strigosus

GOOD DUCK FOOD SOURCES

6. Giant bur-reed, Sparganium eurycarpum
7. Coontail, Ceratophyllum demersum
8. Teal grass, Eragrostis hypnoides
9. Duck potato, Sagittaria latifolia
10. Marsh smartweed, Polygonum muhlenbergii (coccineum)
11. Longleaf pondweed, Potamogeton americanus

FAIR DUCK FOOD SOURCES

12. Buttonbush, Cephalanthus occidentalis
13. Spike rushes, principally Eleocharis palustris
14. Water hemp, Acnida tuberculata
15. Marsh cordgrass, Spartina michauxiana
16. Sago pondweed, Potamogeton pectinatus
17. White waterlily, Castalia (Nymphaea) tuberosa

POOR DUCK FOOD SOURCES

18. River bulrush, Scirpus fluviatilis
19. American lotus, Nelumbo lutea
20. Pickerelweed, Pontederia cordata
21. Marsh mallow, Hibiscus militaris
22. Southern naiad, Najas guadalupensis
23. Wild rice, Zizania aquatica
24. Small pondweed, Potamogeton pusillus
25. Long-leaved ammannia, Ammannia coccinea

APPENDIX A

UPPER MISSISSIPPI RIVER WATER AND LAND CLASSIFICATION SCHEMES

From Minor et al., 1977 - Pool 3 to 10 (excludes linear features)

Class	Symbol	Type Description
Open Water	MCh	Main Channel - the 9-foot channel and all open water between it and the river bank or the first island or the first bed of aquatic vegetation.
	SCh	Side Channel - all free flowing bodies of water separated from the main channel by an island and appear to be navigable by large pleasure boats.
	L	Lake (sometimes referred to as River-Lake) - a non-linear body of water greater than or equal to 10 acres in size and appearing to have little current.
	P	Pond - a small body of open water less than 10 acres in size and appearing to have little current. The borders may be defined by shoreline or aquatic vegetation.
	SS	Sidestream - where substantial acreage is present, it is given as SS in the acreage summary.
	River	River - where large rivers enter from the side, the acreage is shown under River in the acreage summary.
	Sl	Slough - all remaining water bodies whether flowing or stagnant and usually linear in nature.
Aquatic and Marsh Vegetation	Pt	Pontederia (pickerelweed)
	Pg	Phragmites (reed grass)
	Py	Polygonum (Smartweed)
	Cy	Cyperus
	SaL	Sagittaria latifolia (broadleaf arrowhead)
	SaR	Sagittaria rigida (bur arrowhead)
	Sc	Scirpus (bulrush)
	Sp	Sparganium (bur-reed)
	T	Typha (cattail)
	Tm	Cattail marsh-mixture of Typha, Scirpus, Sparganium
	Z	Zizania (wild rice)
	N	Nelumbo (American lotus)
	Ny	Nymphaea (water lily)

Class	Symbol	Type Description
	Po	Potamogeton (pondweed)
	C	Ceratophyllum (coontail)
	Lm	Lemnaceae (duckweeds)
	V	Vallisneria (wild celery)
	10	Nymphaea -Ceratophyllum-Potamogeton-Lemnaceae
	11	Lemnaceae-Ceratophyllum
	12	Sagittaria latifolia - S. rigida
	13	Sagittaria latifolia - Phalaris
	14	Nymphaea-Ceratophyllum-Potamogeton
	15	Sagittaria latifolia - Salix
	17	Lemnaceae-Ceratophyllum-Potamogeton
	18	Nelumbo-Lemnaceae-Ceratophyllum
	19	Vallisneria-Potamogeton-Heteranthra
	22	Scirpus-Sagittaria latifolia
	23	Scirpus-Polygonum
	24	Scripus-Phragmites
	27	Scirpus-Echinocystis-Xanthium-Polygonum
Sand and Mud	S	Bare or sparsely vegetated sand
	Md	Bare or sparsely vegetated mud
Terrestrial Herbaceous Vegetation	G	Grass
	Le	Leersia (rice cutgrass)
	Am	Ambrosia (ragweed)
	M	Upland Meadow - includes a rich variety of brushy plants and grasses and occassional sedges and forbs. Generally, a fairly well-drained site most of the year.
	Sm	Sedge Meadow - less well-drained than upland meadow - includes several species of Carex (sedge) as the dominant vegetation. Also included are Polygonum and other forbs and grasses.

Class	Symbol	Type Description
	Ph	Phalaris (reed canary grass)
	Sr	Spartinia (cord grass)
	Ec	Echinocystis (wild cucumber)
	21	Roadside and levee grass-brush-forb mixture often containing introduced plants.
	28	Leersia-Carex-Sagittaria latifolia-Polygonum (occasional scattering of Scirpus, Sparganium, Typha, Xanthium and other forbs and grasses).
	29	Type 28 covered by Echinocystis (cucumber) - may include a scattering of mixed lowland hardwoods or cottonwood-willow.
	30	Grazed meadow
Woody Vegetation	1a	Cottonwood and/or tree willow with an average height of less than 20 feet.
	1b	Cottonwood and/or tree willow with an average height of greater than 20 feet.
	2a	Mixed lowland hardwoods with an average height of less than 20 feet - principally elm, silver maple and river birch.
	2b	Mixed lowland hardwoods with an average height of greater than 20 feet.
	Px	Plantation -usually red pine or another of the conifers.
	B	Brush - Cornus (dogwood), Cephalanthus (buttonbrush), Rhus (sumac), Sambucus (elderberry), Prunus (choke-cherry and plum), Toxicodendron (poison ivy). All of the above may occur as understory in the forest types - especially poison ivy.
	W	Salix (willow)
	25	Open stand of mixed lowland hardwoods and prominent understory of grass - most likely Phalaris.
Land Use	A	Agricultural - all areas under cultivation or recently cultivated.
	Dp	Park or other developed recreation area such as a boat landing or resort.
	D	Developed - all areas which are unvegetated or marginally vegetated due to man's activities.

Class	Symbol	Type Description
	R	Residential - streets, houses, lawns, shrubs and trees.
	Ro	Rock rip-rap

Classification Scheme from Hagen et al., 1977 - Pool 11 to Cairo, Illinois (excludes linear features)

Class	Symbol	Type Description
Open Water	Mc	Main Channel - the 9-foot navigation channel and all open water between it and the river bank or the first island or the first bed of aquatic vegetation.
	SCh	Side channel - all free flowing bodies of water separated from the main channel by an island and which are not obstructed by a wing dam or closing dam and which appear to be capable of supporting commercial navigation.
	L	Lake - a non-linear body of water greater than or equal to 10 acres in size and having little or no current entering it from the river.
	P	Pond - a natural body of water less than 10 acres in size separated by land from the river, and less than 1.5 times long as it is wide (non-linear).
	SS	Sidestream (classification used for acreage summaries only).
	Sl	All remaining water bodies whether flowing or stagnant and usually linear in nature.
Sand and Mud	S	Water-deposited sand.
	M	Water-deposited mud (sometimes includes wet sand which was difficult to distinguish from mud).

Class	Symbol	Type Description
Aquatic and Marsh Vegetation	Sb	Submergent aquatics
	7	Submergent aquatics and duckweed: Ceratophyllum demersum is often the dominant submergent
	Po	Floating-leaf pondweeds such as Potamogeton americanus; this type was rarely encountered.
	Lm	Lemnaceae (duckweeds) is characteristc of small, stagnant water bodies. In some cases, submergents may have been present but not discernible.
	Ny	Nymphaea (water lily) was rarely encountered.
	N	Nelumbo lutea (American lotus)
	6	Nelumbo lutea and duckweed
	Sa	Sagittaria spp. - primarily latifolia (duck potato).
	Sp	Sparganium spp. - (bur reeds) were uncommon.
	Sc	Scirpus fluviatilis (river bulrush).
	J	Jussiaea sp. (water primrose) - very localized occurrence.
	Py	Polygonum spp. (smartweeds) - a diverse class including emergents and marsh species, annuals and perennials.
	T	Typha latifolia and T. angustifolia.
	E	Eragrostis spp. (love grasses).
Terrestrial Herbaceous Vegatation	G	Mixed grasses (other than Le Ph or E). Not a major type; some overlaps into the marsh category.
	F	Forbs - mixed broadleaf weed species mostly of Eurasian origins; the most common genera include Amaranthus, Xanthium and Ambrosia. Some overlap into the marsh category.
	Le	Leersia oryzoides (rice cut-grass) considerable overlap into marsh category.
	Ph	Phalaris arundinacea (reed canary grass).
	C	Wild cucumber (Echinocystis lobata)
Woody Vegetation	1a	Cottonwood and/or tree willow with an average height of less than 20 feet.
	1b	Cottonwood and/or tree willow with an average height of greater than 20 feet.

Class	Symbol	Type Description
	2a	Mixed lowland hardwoods with an average height of less than 20 feet.
	2b	Mixed lowland hardwoods with an average height of greater than 20 feet.
	Px	Plantation - a stand of planted trees as opposed to one resulting from natural regeneration.
	BB	Buttonbrush (Cephalanthus occidentalis)
	4	Shrub species and/or woody vines which normally do not attain a height greater than 20 feet.
Land Use	A	Agriculture - all areas appearing to have been tilled or pastured within the past year; includes areas tilled and planted for wildlife foods. Abandoned fields are usually typed F.
	G_d	Developed grass - all areas such as most levees which are covered largely by grasses and which are mowed at least once per year; also includes lawns over two acres in size.
	D_P	Developed parks - includes campgrounds, picnic areas, golf courses, and other outdoor recreation areas with developed user facilities. Inclusions such as parking lots or open lawns over two acres in size would be typed as D or G, respectively.
	D	Developed - all areas which are essentially nonvegetated due to man's activities (excluding plowed croplands).
	R	Residential - typically comprised of streets, houses, lawns, shrubs and trees.
Dredged Materials	Dm-	Associated with type 1a, 1b, 2a, 2b, S, M, F or A.

Classification Scheme from Olson and Meyer, 1976a - Pool 1 and 2, and lower Minnesota and lower St. Croix River

Class	Available class breakdowns
Open Water	main channel, main channel border, side channel, slough, lake and pond, and tail water

Class	Available class breakdowns
Sand and Mud	Sand, and mud flat
Aquatic and Marsh Vegetation	Marsh
Terrestrial Herbaceous Vegetation	Meadow
Woody Vegetation	Forest, and brush
Land Use	Agricultural, and residential/commercial

Illinois Waterway Classification Scheme

La Grange to Brandon Road Pool - Bellrose et al., 1977

Alton Pool - USAED, SL, 1980

Class	Available class breakdowns
Open Water	Main channel, main channel border, side channel, slough, lake and pond, and tail water
Sand and Mud	Sand, and mud flat
Aquatic and Marsh Vegetation	Marsh vegetation
Terrestrial Herbaceous Vegetation	Meadow
Woody Vegetation	Forest, and brush (Alton Pool only - forested wetland)
Land Use	Agricultural, and developed

APPENDIX B: MUSSEL SYNONYMS[1]

Nomenclature of Table 4	Synonym[2]
Actinonaias carinata	A. ligamentina
A. ellipsiformis	
Alasmidonta calceola	A. viridis
A. marginata	
Amblema plicata	A. costata, A. peruviana, A. rariplicata
Anodonta grandis	A. corpulenta, A. gigantea
A. imbecillis	Utterbackia imbecillis
A. suborbiculata	
Anodontoides ferussacianus	
Arcidens confragosus	
Carunculina parva	Toxolasma parvus
Cumberlandia monodonta	
Cyclonaias tuberculata	Quadrula tuberculata
Dysnomia triquetra	Truncilla triquetra
Ellipsaria lineolata	Plagiola lineolata
Elliptio crassidens	Unio crassidens
E. dilatata	
Fusconaia ebena	
F. flava	F. undata
Lampsilis higginsi	L. orbiculata
L. ovata	L. ventricosa
L. radiata	L. siliquoidea
L. teres	L. fallaciosa, L. anodontoides
Lasmigona complanata	
L. compressa	
L. costata	
Leptodea fragilis	
L. leptodon	
Ligumia recta	Eurynia recta
L. subrostrata	Eurynia subrostrata
Megalonaias gigantea	M. nervosa, M. heros
Obliquaria reflexa	
Obovaria olivaria	

Plethobasus cyphyus	
Pleurobema cordatum	P. pyramidatum, P. coccineum, P. catillum
Proptera alata	Potamilus alatus
P. capax	Potamilus capax
P. laevissima	Potamilus laevissimus
P. purpurata	Potamilus purpuratus
Quadrula metanevra	
Q. nodulata	
Q. pustulosa	
Q. quadrula	
Simpsoniconcha ambigua	
Strophitus undulatus	S. edentulus, S. rugosus
Tritogonia verrucosa	
Truncilla donaciformis	Amygdalonaias donaciformis
T. truncata	Amygdalonaias truncata
Villosa iris	

1 Sources: Starrett 1971, Fuller 1978. The synonyms were used with Table 4 sources in order to form Table 4. The listing contains only those synonyms that were utilized with Table 4 sources and is by no means complete.

2 Does not include subspecies.

APPENDIX C

Endangered and Threatened
Vertebrate Species other than Fish of GREAT I and
GREAT II Study Areas
Sources: GREAT I, FWWG, 1979; and GREAT II, FWWG, 1980

Status: E - Engangered
T - Threatened

	State and Federal Status[1]					
Mammals	Fed	MN	WI	IA	IL	MO
Keen's Myotis (Myotis keenii)				T		
Gray Bat (Myotis grisecens)	E				E	E
Indiana Bat (Myotis sodalis)	E			E	E	E
Evening Bat (Nycticeius humeralis)				T		
White-tailed Jackrabbit (Lepus townsendii)						E
Woodland vole (Microtus pinetorum)				E		
River Otter (Lutra canadensis)				T	T	E
Bobcat (Felis rufus)				E	T	
Black Bear (Ursus americana)				E		
Birds						
Double-crested Cormorant (Phalacrocorax auritus)			E		E	E
Great Egret (Casmerodius alba)			T		E	
Black-crowned Night Heron (Nycticorax nycticorax)					E	
Sharp-shinned Hawk (Accipiter striatus)				E		E
Cooper's Hawk (Accipiter cooperii)			T	T	E	E
Red-shouldered Hawk (Buteo lineatus)			T	E	E	
Swainson's Hawk (Bueto swainsoni)					E	
Broad-winged Hawk (Buteo playterus)				T		
Bald Eagle (Haliaeetus leucocephalus)	E		E	E	E	
Marsh Hawk (Circus cyaneus)				E	E	E
Osprey (Pandion haliaetus)			E		E	E
American Peregrine Falcon (Falco peregrinus anatum)	E	E	E	E	E	E
Arctic Peregrine Falcon (Falco peregrinus tundrius)	E					
Common Gallinile (Gallinula chloropus)					T	
Black Rail (Laterallus jamaicensis)					E	
Yellow Rail (Coturnicops horeboracensis)			T		E	
Upland Sandpiper (Bartramia longicauda)				E	E	
Wilson's Phalarope (Steganopus tricolor)					E	
Forster's Tern (Sterna forsteri)			E		E	
Least Tern (Sterna albifrons)				E		E
Barn Owl (Tyto alba)					E	E
Short-eared Owl (Asio flammeus)					E	
Long-eared Owl (Asio otus)				T	E	
Veery (Catharus fuscescens)					T	
Blue-winged warbler (Vermivora pinus)				T		
Brown Creeper (Certhia familiaris)					E	
Yellow-headed Blackbird (Xanthocephalus xanthocephalus)					E	
Henslow's Sparrow (Ammodramus henslowii)					T	
Bobwhite Quail (Colinus virginianus)		T				

Amphibians and Reptiles	State and Federal Status[1]					
	Fed	MN	WI	IA	IL	MO
Central Newt (Notopthalmus viridescens louisianensis)				E		
Cricket Frog (Acris crepitans blanchardi)		T				
Pickerel Frog (Rana palustris)			T			
Burn's Leopard Frog (Rana pipiensburnsii)			T			
Wood Frog (Rana sylvatica)						E
Red-eared Turtle (Chrysemys scripta)				T		
Wood Turtle (Clemmys insulpta)			E			
Blanding's Turtle (Emydoidea blandingi)			T	T		E
Illinois Mud Turtle (Kinosternon flavescens spooneri)				E	E	
Stinkpot (Sternotherus odoratur)				T		
Ornate Box Turtle (Terrapeno o. ornata)			E	T		
Five-lined Skink (Eumeces facciatus)				T		
Western Slender Glass Lizard (Ophisaurus a. attenvatus)				E		
Northern Copperhead (Agkistrodon contortrix)				E		
Black Rat Snake (Elaphe o. obsoleta)				T		
Western Hognose Snake (Heterodon nasicus)					T	
Speckled Kingsnake (Lampropeltis getulus holbrooki)				E		
Yellow-bellied Water Snake (Natrix erythrogaster)				T		
Graham's Water Snake (Natrix grahami)				T		
Diamondback Water Snake (Natrix rhombifera)				T		
Queen Snake (Natrix septemvittata)			E			
Massasauga (Sistrurus catenatus)		T	E	T		
Western Ribbon Snake (Thamnophis proximus)			E			

[1] Fed - Federal
MN - Minnesota
WI - Wisconsin
IA - Iowa
IL - Illinois
MO - Missouri

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